RELIEF MAP OF NORTHERN CALIFORNIA.

 Issued March 15, 1909.

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 207.

A. C. TRUE, Director.

IRRIGATION IN THE SACRAMENTO VALLEY, CALIFORNIA

BY

SAMUEL FORTIER,
Chief of Irrigation Investigations,

ASSISTED BY

O. W. BRYANT, J. E. ROADHOUSE, A. E. WRIGHT,
AND J. H. BARBER.

(Based on work done in cooperation between the Office of Experiment Stations and the State of California.)

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1909.

OFFICE OF EXPERIMENT STATIONS.

A. C. TRUE, Director.
E. W. ALLEN, Assistant Director.

IRRIGATION INVESTIGATIONS.

SAMUEL FORTIER, Chief.
R. P. TEELE, Editorial Assistant and Acting Chief in absence of the Chief.

IRRIGATION ENGINEERS AND IRRIGATION MANAGERS.

A. P. STOVER, Irrigation Engineer, in charge of work in Oregon.
C. E. TAIT, Irrigation Engineer, in charge of work in Imperial Valley and Arizona.
F. W. ROEDING, Irrigation Manager, in charge of work in California.
S. O. JAYNE, Irrigation Manager, in charge of work in Washington.
W. W. MCLAUGHLIN, Irrigation Engineer, in charge of work in Utah.
P. E. FULLER, Irrigation Engineer, in charge of power investigations.
O. W. BRYANT, Irrigation Manager, in charge of work in Colorado and Wyoming.
W. L. ROCKWELL, Irrigation Manager, in charge of work in Texas.

ASSISTANT IRRIGATION ENGINEERS.

V. M. CONE, H. I. MOORE and F. L. BIXBY.

COLLABORATORS.

O. V. P. STOUT, University of Nebraska, in charge of work in Nebraska.
BURTON P. FLEMING, New Mexico Agricultural College, in charge of work in New Mexico.
GORDON H. TRUE, University of Nevada, in charge of work in Nevada.
ELIAS NELSON, Idaho Agricultural College, in charge of work in Idaho.
W. B. GREGORY, Tulane University of Louisiana, in charge of rice irrigation in Louisiana and Texas.
HERBERT T. NOWELL, University of Wyoming, studies of duty of water in Wyoming.

IRRIGATION FARMERS.

JOHN GORDON, R. G. HEMPHILL, W. H. LAUCK, R. E. MAHONEY, and JOHN KRALL, Jr.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., November 28, 1908.

SIR: I have the honor to transmit herewith a report on irrigation in the Sacramento Valley, California, prepared by Dr. Samuel Fortier, chief of irrigation investigations, of this Office. The work on which this report is based was done in cooperation between this Office and the State of California, each paying one-half the expense.

The Sacramento Valley has been one of the great wheat-producing areas of the United States, but grain farming in the valley has been on the decline for many years. The change from grain raising to general agriculture is now taking place, and the highest development of the valley requires the irrigation of most of its lands. This report shows the advantages to be derived from irrigation and discusses possibilities, methods, and costs. It is recommended that the report be published as a bulletin of this Office.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

ILLUSTRATIONS.

IRRIGATION IN THE SACRAMENTO VALLEY, CALIFORNIA.

INTRODUCTION.

The investigations, the results of which are given herein, form part of the cooperative work in irrigation which has been carried on in different parts of California for a number of years under annual agreements between the State board of examiners[a] and the State engineer, representing the State of California, and the Director of the Office of Experiment Stations of the United States Department of Agriculture. The funds used have been contributed in equal amounts by the two parties to these agreements. The position which the Sacramento Valley occupies in relation to the northern portion of the State and its general topographic features are shown in the frontispiece. It will be seen from this relief map that this valley forms the northern part of the great central plain of California. That portion of the central plain with which this report deals has a length of about 150 miles and a varying width of 35 to 50 miles between the foothills of the Sierras and those of the Coast Range. It will be seen also that the Sacramento River, its main drainage artery, heads in the vicinity of Mount Shasta in the northern part of the State, and that its flow is increased by a number of tributaries, chief of which is the Feather River, which drains a part of the main range of the Sierras.

Those who have observed the wonderful development under irrigation which has taken place in other fertile valleys of the arid region have been disappointed in this part of California. The casual observer has not been able to account for the wide stretches of brown summer fallow and the poor crops of grain when so high profits might be made under more intensive farming supplemented by irrigation. Yet the reasons why this valley has not reached a higher state of development are not difficult to find. Its very advantages in the way of fertile soil, heavy winter rainfall, and favorable climate have held it back. Had the soil been of poorer quality, the rainfall

[a] The present board is composed of Gov. J. N. Gillette; C. F. Curry, secretary of state; and U. S. Webb, attorney-general; while Hon. N. Ellery is State engineer.

less abundant in winter, or the climate too cold for the winter growth of plants, it is probable that the entire valley would be irrigated now. Largely because grain and grain hay could be grown during the winter months and matured in the spring, property owners have been slow to provide a water supply and fit the soil for the artificial application of water. The large size of the majority of the holdings also has retarded development under irrigation. So long as large yields were the rule farmers tried to increase their acreage, and when grain raising became less profitable the difficulties in the way of irrigating even a small part of a large ranch were not overcome readily. From the point of view of the owner there seemed to be no practical way of irrigating several thousand acres and at the same time of retaining possession of it. It also seemed to be futile to attempt to join hands with one's neighbors to provide a common water supply, because of the absence of a united public opinion favorable to irrigation.

In making a study of the irrigation conditions and possibilities of a drainage basin nearly one-half as large as the State of Illinois, it was found impossible to cover the entire area in a thorough manner. Besides, such a course did not seem necessary. It was thought possible to present with a fair degree of accuracy conditions as they exist throughout the entire area by making detailed studies of a few representative localities and examining in a more general way the remainder of the territory.

In pursuance of this plan, in the spring of 1906, Mr. J. H. Barber was placed in charge of investigations under the canals of the Yolo County Consolidated Water Company in Yolo County. This system was selected mainly for the reason that it includes the Moore Ditch, which is one of the oldest in the valley. Conditions here have become somewhat fixed, and the present methods may be regarded as the result of an experience in the use of water extending over thirty years.

A little later in the same year, at the earnest solicitation of the officers of the Sacramento Valley Development Association and of the Water Users' Association of Orland, Cal., investigations were begun by O. W. Bryant under the canals of Stony Creek Irrigation Company in the northern part of Glenn County.

During 1907 the investigations have been extended to include the Central Canal, which irrigates lands on the west side of the Sacramento River, the work being done by O. W. Bryant and J. E. Roadhouse; and the Butte County Canal, which derives its supply from Feather River and irrigates portions of Butte and Sutter counties, the work in this section being done by A. E. Wright. The reports covering these sections were prepared by the men named.

While this bulletin contains reports on these four irrigation enterprises, it would be incomplete without an introductory chapter dealing in a more general way with the present situation. The valley is now in a transitional stage. Several of the large grain ranches have been sold to land and irrigation companies which have provided, or are proceeding to provide, a water supply. As soon as this is done the land is subdivided and sold to settlers in small holdings. These sales mean much more than ordinary land transfers. They involve a radical change in crops, farming operations, and methods. The new man on the small farm can not afford to raise grain. In order to make a living he must grow alfalfa, fruit, and vegetables, and as a rule these must be irrigated. This transformation from dry farming to irrigation and the proper preparation of the surface of fields will involve large outlays. Then, too, a large part of the valley is subject to overflow, and costly protective works are necessary before the flooded areas can be improved and rendered profitable. It will thus be seen that the agricultural development of the Sacramento Valley involves three operations, whose magnitude can be best understood by giving an estimate of the amount of capital required to accomplish each: (1) Protective works to control floods, $24,000,000; (2) providing a water supply for irrigation, $50,000,000; and (3) preparing the land for irrigation, $35,000,000. These facts and figures seem to warrant the writer in presenting a brief review of the agricultural situation as it exists to-day.

EARLY EFFORTS AT DEVELOPMENT.

During the nearly eighty years of Spanish and Mexican rule in California the great central plain, with its 400 miles of arable lands stretching between the Coast and Sierra ranges, was the abode of Indians, wild animals, and an occasional white trapper. Its transformation into cultivated fields was the work of Anglo-Saxons. Were it not for the large tracts of land on the borders of the interior streams which were given away under both Spanish and Mexican rule, little would remain of the influence of that period. Neither the upper portion of this central plain, known later as the Sacramento Valley, nor the lower portion now designated the San Joaquin Valley, received much benefit agriculturally from that chain of missions which was established along the coast from San Diego on the south to San Francisco on the north.

The efforts of the Spanish missionaries were not directed to any great degree toward the improvement of agricultural practice. Their methods and those of their followers were of the crudest and far behind those of the Americans of that day on the Atlantic seaboard. As late as 1848 a forked limb of a tree, shod with a piece of iron and

drawn by oxen hitched by the horns, served the purpose of a plow. The harrow was a bundle of brush, the reaper a sickle or a knife, and the thrashing machine the hoofs of young horses.

There was no commerce and the manufacturing was limited to the use of homemade looms and wine presses and crude attempts at tanning leather. Native horses were so cheap and numerous that they were frequently killed to save the grass for cattle, which were valued chiefly for their hides and tallow.

From an agricultural point of view, the first half of the nineteenth century in California is important chiefly as being the period of the Spanish and Mexican land grants. Before the termination of Spanish rule in 1822 about thirty ranches or farms had been granted. As a means of colonization under Mexican independence the number was greatly increased, and in 1846 no less than eight hundred large tracts containing some of the best land in the State had been given away. These land grants have from that day to the present exerted a powerful influence in shaping the destiny of this Commonwealth. At the cession of California to the United States in 1848 there were comparatively few Spaniards or Mexicans north of San Francisco, and the influence of these, outside of a few prominent individuals like General Vallejo and Señor Martinez, was not sufficient to make any lasting impressions. In no sense is this true of the land grants along the Sacramento River and its tributaries. These have so controlled the agricultural as well as the commercial and social development of that part of the State that it would not be possible to convey to minds unfamiliar with the situation a correct idea of the irrigation conditions and possibilities of this valley without some reference to the size and character of the landholdings.

The following summary shows that prior to 1848 grants aggregating 980,399 acres had been made to residents of the nine counties in the Sacramento Valley. The number given in the table is slightly in excess of the number of original grants for the reason that a few were subsequently divided by county lines. Thus, for example, the Capay grant to J. Soto, comprising 44,388 acres, was cut in two by the north boundary of Glenn County. This political division left 20,388 acres in Tehama County and the balance in Glenn County.

Spanish and Mexican land grants in Sacramento Valley.

County.	Number of land grants.	Total area.	County.	Number of land grants.	Total area.
		Acres.			*Acres.*
Yolo	5	91,970	Solano	8	146,379
Yuba	3	78,653	Sutter	2	23,545
Colusa and Glenn	6	156,262	Tehama	7	131,379
Sacramento	8	202,330			
Butte	8	149,881	Total	47	980,399

The Rancho del Arroyo Chico, situated in the heart of the valley and owned by the late John Bidwell, may be taken as a type of those that were successfully managed. This grant comprised 22,214 acres. As early as 1857, 225 acres were planted to wheat, 75 acres to barley and oats, and 8 acres to corn. There were on the ranch also at that time 1,200 bearing orchard trees, 15,000 vines, 600 cattle, and 500 horses. About 25 Indians were employed constantly, and not infrequently from 15 to 20 white men. The farm structures consisted of a large adobe dwelling and outbuildings, a wooden store and granary, blacksmith and wagon shops, barn, and flouring mill. Improvements made on this ranch more than kept pace with the general agriculture in the valley, and from this small beginning the cultivated area was increased in twenty-three years to 9,000 acres in wheat and barley, besides a corresponding increase in orchards and a doubling of the live stock.

During the past half century many of the old grants have been subdivided, but the numerous large estates which have been acquired since the United States gained possession have tended to make this part of the State one of large holdings. In 1892 the late W. H. Mills estimated that the holdings of 100 proprietors in the Sacramento Valley aggregated 1,600,000 acres, or an average of 16,000 acres to the landlord. The year previous, William Ham Hall, ex-State engineer, in a report on the central irrigation district, located in portions of Glenn and Colusa counties, stated that 40 owners held 89,000 acres of the total of 156,550 acres comprised in the district, yet this district when compared with the entire valley, if one excepts a few large ranches, is one of small rather than large holdings.

SOILS.

The soil of the Sacramento Valley is for the most part an alluvial loam of great depth and richness. The beds of new canals when excavated from 2 to 3 feet deep frequently bear a luxuriant crop of weeds before water is turned in. The lands adjacent to the main streams and much of the overflowed lands are not only productive but contain sufficient sand and gravel to be easily tilled. Heavier clay lands occur on the west side, about midway between the Sacramento River and the western foothills. These so-called "goose lands" occupy a narrow belt in the trough of the valley and extend from Willows south a distance of 50 miles or more. Somewhat similar soils occur on the east side, west of Feather River. The results of analyses made by Doctors Hilgard and Loughridge, of the State experiment station, have shown that these heavier clay soils are rich in all the more valuable elements of plant food. To convert them from low-producing grain and pasture lands into profitable alfalfa lands all that is

required is artificial drainage in February, March, and April and the application of irrigation water in June, July, August, and September. In addition to these two typical soils, there is the red soil which is found around the rim of the valley and the black adobe clay which occupies limited portions of the floor.

For a more complete description of the character of the soils of that portion of the valley occupying the north central part of the western half and covering an area of somewhat less than a half million acres, the reader is referred to a report of the Bureau of Soils entitled "The Soil Survey of the Colusa Area of California," made by Messrs. Lapham, Sweet, Strahorn, and Holmes.

CROPS.

The products of the soil include nearly every profitable crop which can be grown in the arid region. The traveler in passing through the valley and viewing the large ranches gets the impression that it is little more than a grain-producing section, but hidden behind undulations and skirting the streams are many orchards and vineyards. These orchards include most of the varieties of fruit trees found in the United States. Certain soils and climatic conditions favor particular varieties. In one district it is sweet cherries, in another French prunes, in still others peaches, apricots, pears, figs, olives, walnuts, or almonds. Then, again, all these varieties and more may be found on the same ranch. Nor are the orchards confined to deciduous trees. In 1906, according to the assessor's returns, Butte County had nearly one-third as many orange trees in bearing as Los Angeles County. In 1906 Sacramento County had over 16,000 acres of table, raisin, and wine grapes in bearing, while the combined acreage in the remaining counties of the valley approached that of Sacramento in extent. Phenomenal yields of vegetables are obtained on alluvial lands bordering the streams. A large part of the potatoes, cabbage, asparagus, celery, and beans consumed in San Francisco, Oakland, and other Bay cities are raised near the junction of the Sacramento and San Joaquin valleys. As irrigation is extended more alfalfa is planted, and, as this plant grows in winter as well as in summer, 20 acres is usually enough to maintain a herd of 20 cows the year through.

RELATION OF CLIMATE TO IRRIGATION.

A study of the climate of the Sacramento Valley, and particularly of the rainfall and temperature, reveals the necessity for irrigation. Out of some 32 rain-gauging stations scattered throughout the valley, 18 have been selected as representative of the different localities. The lengths of the records at these stations vary from eleven to

thirty-six years and average twenty-four years. The records of precipitation at each of these 18 stations have been averaged for each month in the year and the average of these stations is shown graphically in the accompanying diagram (fig. 1). From this it is seen that considering the valley as a unit and taking an average of all the rain which falls upon it, January is the wettest month, with a little over 4 inches. December is next, with less than 3.5 inches, while February and March are in the third class, having less than 3 inches. Of the summer months, June, July, and August may be said to be rainless, while the amounts which fall in May and September are seldom sufficient to be of benefit to plants.

In temperate climates there is what is termed a "growing period," in which cultivated plants either reach maturity or produce seed, and this is followed by a period of rest, in which most plants are dormant. Considering the rainfall for these two periods in the

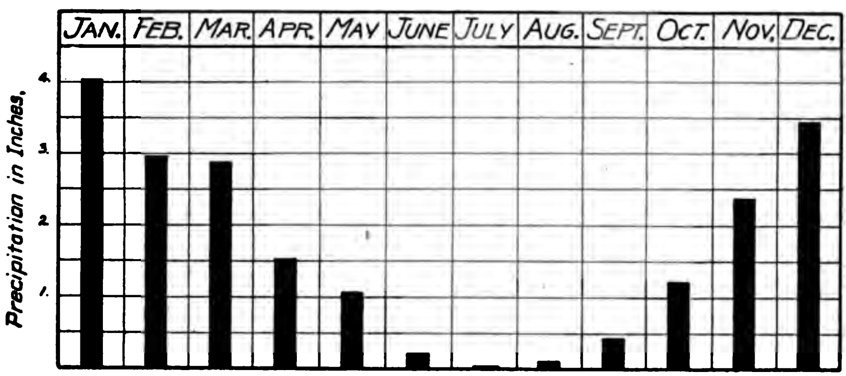

FIG. 1.—Average monthly rainfall, Sacramento Valley.

Sacramento Valley and dividing the year into two equal parts, from April 1 to September 30, and from October 1 to March 31, the average amount of rainfall in the first, or growing, period is 3.36 inches, as compared with 16.92 inches in the second period.

In this connection it is interesting to compare the monthly rainfall of Milan, Italy, located in the heart of a valley which has been irrigated for centuries, with that of the Sacramento Valley, where the landowners have not fully decided whether irrigation is needed. Figure 2 shows the average monthly rainfall at Milan for eighty years. No more convincing argument than a comparison of these two diagrams could be presented to show the need of irrigation in the Sacramento Valley.

The temperature records of the valley likewise show the necessity for irrigation.

The temperatures shown on figure 3 were obtained by taking an average of the mean monthly temperature records at 18 stations for a period of five years. July, with an average mean of 79° F., is the hottest month, while August has 77° and June 75°. From midsum-

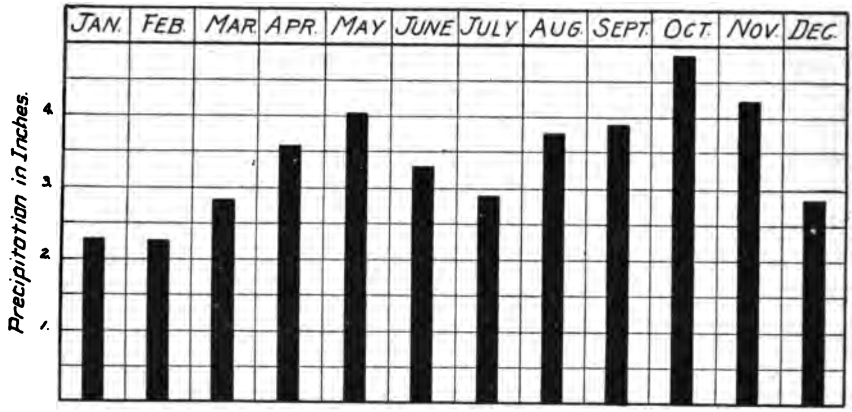

FIG. 2.—Average monthly rainfall, Milan, Italy.

mer to December (which has a mean temperature of 47°) there is a gradual decline, and from January to July a gradual rise in temperature. The effect of the long, hot summer upon cultivated soil is to rob it by evaporation of the greater part of the previous winter's

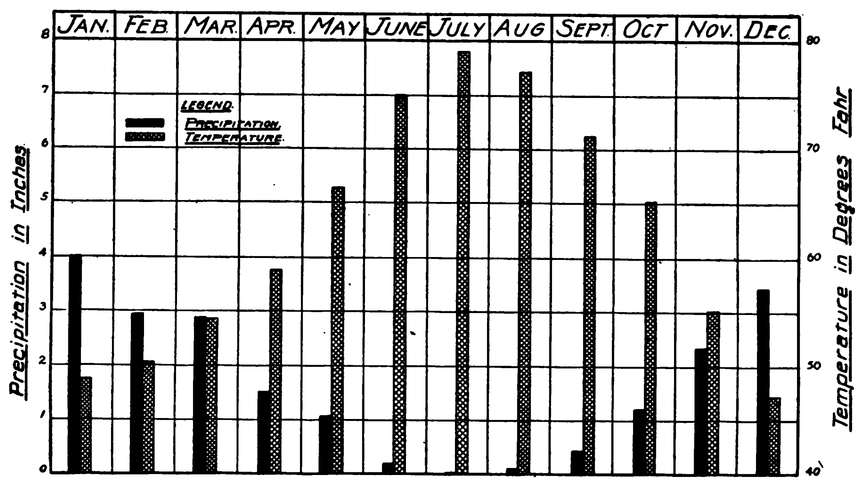

FIG. 3.—Mean monthly temperature and precipitation, Sacramento Valley.

rainfall. This is shown in a way by figure 4, which represents the average monthly evaporation from a free water surface at Chico, Cal., for the years 1904 and 1905. While it is true that the rate of evaporation from a water surface differs from that from a soil surface,

yet in both cases temperature is the controlling factor. The results of an experiment carried on at Chico during the spring of 1905 showed that the loss of water by evaporation from the surface of cultivated but uncropped lands of the Sacramento Valley was equivalent to a depth of 5 inches over the surface from February 9 to May 9, while the evaporation from a water surface under similar conditions was 9.06 inches.

Owing to the mild winter climate of the Sacramento Valley and the absence of snow and severe frosts, farmers from the time of its first settlement have found it profitable to plant wheat and barley during the winter months and harvest the crop near the close of the following spring. These hardy grains, as well as the native clovers and grasses, make slow growth during the winter, but, having their

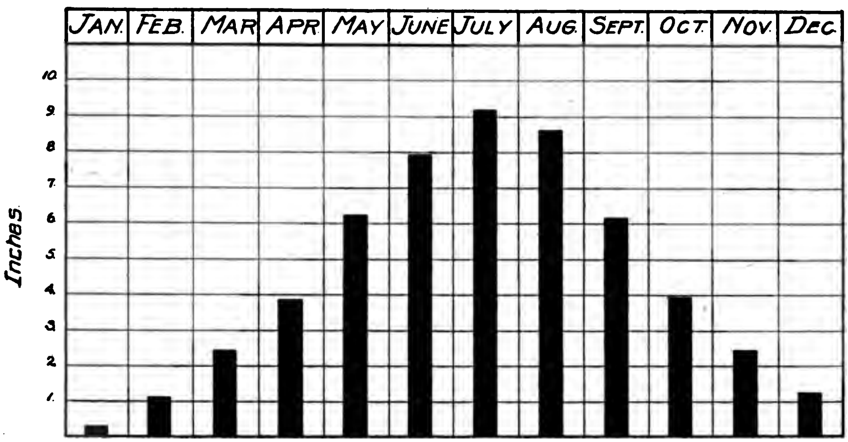

FIG. 4.—Average monthly evaporation, Chico, Cal., 1904–1905.

roots established, their growth is rapid during the warmer spring months. The abundant rainfall of this period is likewise an essential factor. Sometimes there is an excess of soil moisture. The average rainfall in the valley during December, January, February, and March is 13⅓ inches, or what would amount to 40 inches annually if this rate continued over the entire year. This winter precipitation, equaling that of humid countries and occurring at a time when fogs are common and evaporation losses small, frequently makes the soil too wet to work and retards farming operations. This is more particularly true of low-lying lands and the remedy for this excess of moisture is discussed under drainage (p. 16).

December seeding and June harvesting leave the land uncropped the balance of the year. This grain crop and the large amount of soil moisture which is lost by evaporation, run-off, and deep percolation, exhaust the rainfall of the previous months and leave little to

nourish shallow-rooted plants. The result is that there is a parched and lifeless waste of hundreds of thousands of acres from the ripening of the grain in May until after the first drenching rains of October or November. In other words, all this great expanse of alluvial soil, except the limited areas that are planted to vines and orchards or are irrigated, lies dormant in summer-fallow or in stubble through the long, dry summer.

It is thus evident that the farmer who depends on the clouds for his supply of water is placed at a disadvantage. He tries to take advantage of winter rains by growing crops in January, February, and March, when there is little growth in the soil, and his lands remain unplanted and uncropped during the summer months, when most plants grow with great rapidity if artificially watered.

Deep-rooted plants, such as vines and to some extent orchard trees, are exceptions. Deep soils retain sufficient moisture for the growth of such plants during a rainless summer. The rate of growth and the quantity of fruit may be less than if a small amount of water were judiciously applied in irrigation, and the quality may not be so good, but fairly good yields without irrigation have been the rule rather than the exception in both vineyards and orchards. For such crops in this climate irrigation is supplemental to the rainfall.

In calling attention to the worst features of the climate of the Sacramento Valley, in order to demonstrate the necessity of irrigating crops like alfalfa, one should not neglect to state that this same climate possesses a great many excellent features. It is, in fact, the chief asset from the standpoint of agriculture under irrigation. At Sacramento only once in thirty years has the temperature gone below 22° F., and during the same period the number of days in which the temperature has reached 30° or lower has averaged but five in each year.

The mild winters, with no heavier rainfall than Ohio, do away with the necessity of providing barns, stables, and other shelter for domestic animals. Farm operations can likewise be carried on throughout the year without interference from frost or snow. The excellence of the climate is further shown by the diversity of products that can be successfully grown. The wide range of vegetation that lies between the tender eucalyptus and the hardy cottonwood, the semitropical orange and the Siberian crab tree, can be imagined more readily than expressed.

SACRAMENTO VALLEY LANDS SUBJECT TO OVERFLOW.

In the Sacramento Valley from the mouth of Stony Creek, near Chico, south to Brannan, opposite Rio Vista, there are over a million acres subject to overflow in high floods. Ordinary floods cover from

500,000 to 750,000 acres. The magnitude of this problem of flood prevention can better be understood when one considers that the total arable and irrigable area in the floor of the valley is about 2,500,000 acres and that from one-fifth to two-fifths of this area, comprising by far the most fertile portion, is liable to be flooded. This ever-present menace of inundation during periods of high water greatly retards permanent land improvements. Were it not for this danger, these river bottoms would now be the most valuable as well as the most productive general farming lands in the State. It is but just to the enterprise of the Californians to state that immense sums have been expended during the past forty years in protective works. Numerous levee districts have been organized and a large amount of work done under each. Although each of these enterprises appeared large to the small number of landowners who paid the bills, yet each was small in comparison to the total amount of protection required. Unfortunately, also, all of these attempts at flood protection have been made and all of the funds expended without any reference to any general plan for the protection of the entire flooded portion of the valley. This broad view which is so essential in any undertaking of this character has been wholly lost sight of, and individuals and communities have joined hands in an effort to protect their individual and community interests without due consideration of the needs of other landholders, or of how such construction would affect the interests of these outsiders or of the settlers in the valley generally.

To rectify this mistake and for the purpose of having all work done in conformity to a definite plan that would take in all of the essential features, a State river convention was called in San Francisco on May 23, 1904. This convention after a full discussion of the subject decided to form a permanent association to be known as the River Improvement and Drainage Association of California, and to recommend the appointment of a commission of engineers to investigate river and flood conditions in the Sacramento and San Joaquin valleys and submit a general plan for their improvement and control.

As finally constituted the commission was composed of Maj. T. G. Dabney, chief engineer of the Yazoo (Miss.) Delta levee district; Maj. Henry B. Richardson, member of the United States Mississippi River Commission; Lieut. Col. H. M. Chittenden, U. S. Army, in charge of the Yellowstone Park and Missouri River; and M. A. Nurse, chief engineer to the commissioner of public works for California.

The report of this commission was submitted December 15, 1904, and consists of three main recommendations. In the first of these

it is planned to build substantial levees of the general form shown in the accompanying sketch (fig. 5.) on each side of the Sacramento River from its mouth to Stony Creek, similar levees to be built along the main tributaries until sufficiently high ground is reached. At all points ample space is to be left between levee lines to enable the maximum flood to pass. The length of double levees on the Sacramento River is estimated at 176 miles, or 352 miles of single levee, varying in height from 8 to 21 feet and aggregating nearly 50,000,000 cubic yards. This yardage when increased by that required to build levees on the Feather and American rivers amounts to 61,500,000 cubic yards, which, at prices ranging from 10 to 15 cents per yard, calls for an expenditure of nearly $7,000,000.

Another prominent feature of the proposed plan is to correct the alignment of the river by cut-offs where necessary, and to increase its channel capacity by mechanical means wherever current action fails to accomplish this purpose. The material required for the levees if obtained wholly from the river side of each embankment

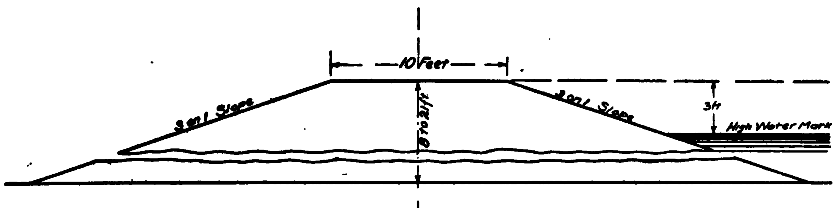

FIG. 5.—Proposed standard levee for the Sacramento River. The height varies from 8 to 21 feet.

would help to enlarge the channel. The additional amount of channel excavation required, together with the excavation of projecting points and the new channels across bends, aggregates nearly 79,000,000 cubic yards, which, at prices varying from 7 to 15 cents a yard, figure up to over $7,250,000.

The third recommendation of the commission deals with collecting the hill drainage which now collects during flood periods in large natural basins, and conducting it to the river at various points by drainage canals. The excavation of these drainage canals, and the removal of the water which collects in the natural basins, together with the necessary structures, are estimated to cost nearly $5,000,000.

The levees, channel development, drainage canals, incidentals, and administrative expenses bring the total figure up to nearly $24,000,000. This estimate was based on data collected prior to the great flood of 1907, and as this flood far exceeded all others of which records have been taken, it is probably too low.

The beneficial results to be derived from this expenditure may be summed up briefly in the statement that it would render possible

the highest agricultural development of from 500,000 to 1,000,000 acres of extremely fertile land which is at present of comparatively little value. It would likewise be an aid to navigation and greatly improve the sanitary conditions of the great central plain of California.

It has been proposed that the total expense be shared equally by the National Government, the State of California, and the interested property owners. This arrangement would be favorable to the owners of land within the flooded territory, and as a concession to both the State and the Nation for this financial assistance they should agree to reduce their holdings to a maximum of 160 acres. In the opinion of the writer, neither the State nor the Federal Government should contribute any funds that would tend either directly or indirectly to foster landlordism on the banks of the Sacramento. The value of the reclaimed lands would increase many fold, and large holdings could be disposed of at a high profit above the cost of protection.

With complete protection and subdivision into small holdings, all other improvements would follow rapidly. The irrigation of these lands presents no serious difficulties. For most crops from one to three irrigations in midsummer would suffice, and the water could be readily and cheaply pumped either from the river direct or from wells.

WATER SUPPLY.

The most striking characteristic of the streams of the Sacramento Basin is their wide fluctuation between early spring and late summer. Unlike most western rivers, these reach their highest discharge in March instead of May and June. This is due to the mild winter climate, the heavy rainfall in January, February, and March, and the small percentage of the flow which comes from melted snow.

To enable the reader to form a fairly correct idea of the available water supply the records of stream measurements have been collected, tabulated, and presented in the form of diagrams, which are shown in figures 6 to 13. These records have been obtained for the most part from the published reports of the United States Geological Survey, and include the average monthly flow of four to six years, except for Putah Creek, which covers two years. In most cases the streams were measured at favorable points around the rim of the valley, so that the flow as given represents for each stream the amount available for irrigation purposes. The same fact is represented more generally in figure 14, which shows the combined average flow of all the principal streams entering the valley for the respective periods stated in the diagrams for the individual streams.

The combined monthly flow, as represented graphically in figure 14, is given in cubic feet per second and also in acre-feet in the following table. The following streams are included: Sacramento River at Red Bluff, Feather River at Oroville, American River at Fairoaks, Yuba River at Smartsville, Bear River near Wheatland, Stony Creek near Fruto, Cache Creek near Yolo, and Putah Creek at Winters.

Combined flow of streams of the Sacramento Valley.

Month.	Mean flow.	Total monthly flow.	Month.	Mean flow.	Total monthly flow.
	Cubic feet per second.	*Acre-feet.*		*Cubic feet per second.*	*Acre-feet.*
January	53,943	3,316,824	August	9,195	565,378
February	66,878	3,714,214	September	8,347	496,681
March	99,702	6,130,434	October	9,880	604,497
April	72,392	4,307,621	November	17,737	1,055,424
May	58,142	3,575,010	December	26,413	1,624,071
June	38,646	2,299,595			
July	16,548	1,017,496	Total	477,823	28,707,245

A study of the foregoing table and the accompanying diagram (fig. 14) reveals the situation in the Sacramento Valley as regards the water supply. The greatest discharge is in March and the least in September. The flow in March is eleven to twelve times as great as it is in either August or September. In the first-named month water has practically no value to the farmer for irrigation purposes

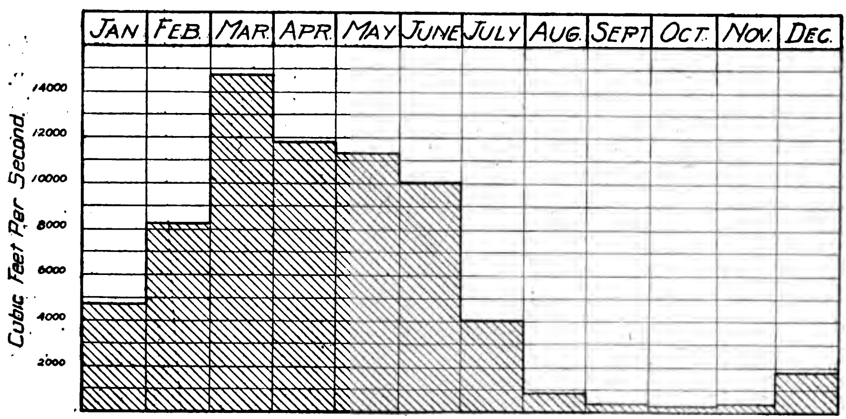

FIG. 6.—Monthly discharge of American River near Fairoaks, 1905–1907.

unless stored; only that which is found in the channels of streams after the rains have ceased can be utilized in growing crops.

This calls attention to the necessity for building storage reservoirs to hold back the waters of the early spring months for use in midsummer. It is clear that not all the arable land of the valley can be irrigated without the use of storage reservoirs. Yet if we consider

the years for which records were taken as representing years of average water supply, a large area of land can be irrigated without resorting to storage. There is an abundant supply for May and June and a reasonably large amount for July for the entire valley. It is chiefly for the months of August and September that storage

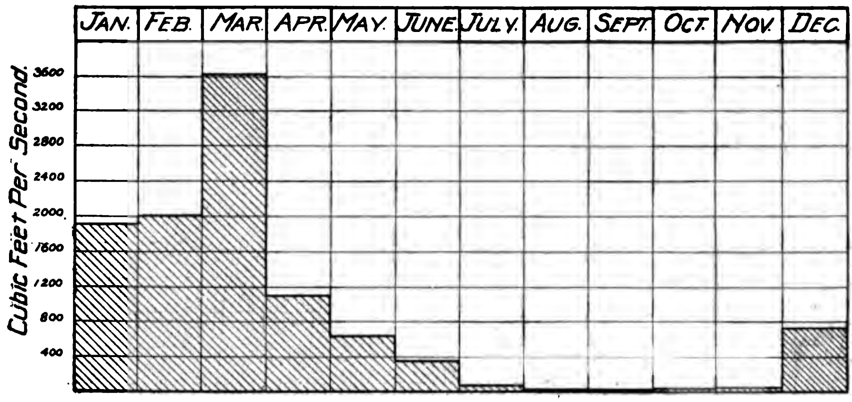

FIG. 7.—Monthly discharge of Bear River near Wheatland, 1905–1907.

is a necessity. By using heavier irrigations when water is abundant and lighter irrigations when it is scanty, it is possible to irrigate a large part of the entire acreage. If we assume that the irrigators of the valley will apply in years of average water supply 6 inches in depth over the surface in May, 9 inches in June, 9 inches in July,

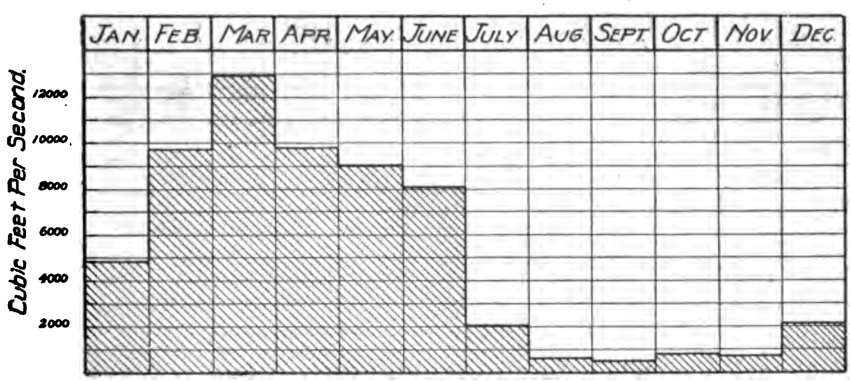

FIG. 8.—Monthly discharge of Yuba River near Smartsville, 1905–1907.

6 inches in August, and 6 inches in September, there would be sufficient water, taking the figures given, to irrigate a million acres. In dry years more water might be applied in May and June and less in July, August, and September.

In making this estimate it is likewise taken for granted that water for irrigation will have a higher value than water for navigation,

and that when the higher portions of the valley are irrigated the passage of boats between Knights Landing and Chico in midsummer will be impracticable. For years the traffic on this part of the river has not been worth considering, and as transportation by rail is

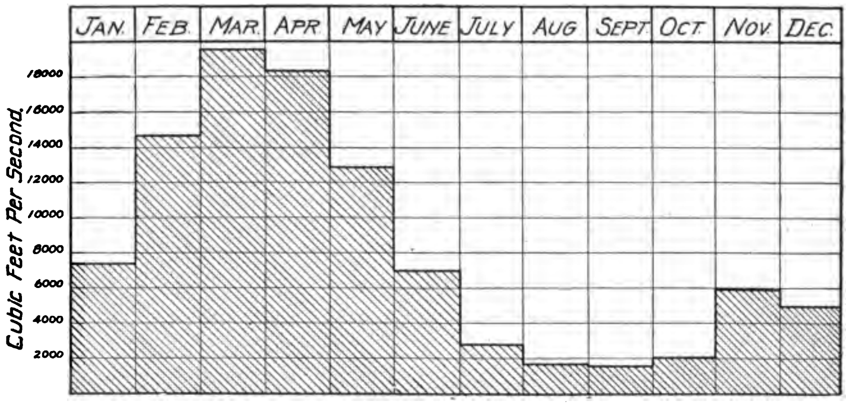

FIG. 9.—Monthly discharge of Feather River at Oroville, 1902–1906.

extended, improved, and cheapened there will be less need to use the river for this purpose. During the past year over 100 miles of electric railways have been built and many more lines are projected. One is therefore reasonably safe in predicting that, owing to the low cost

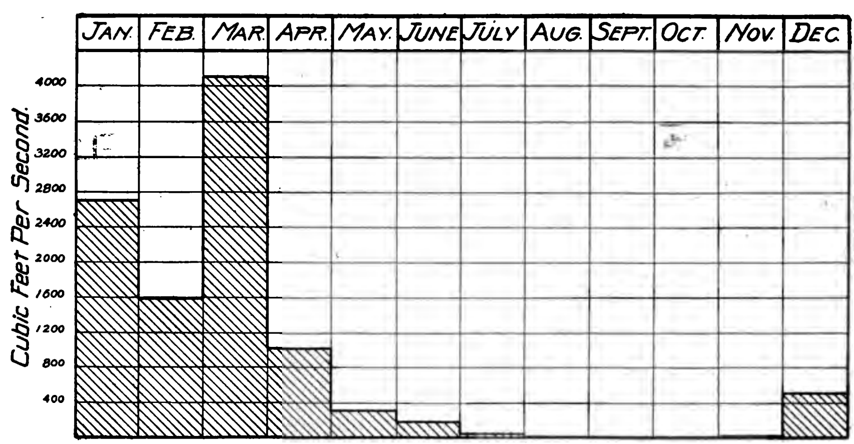

FIG. 10.—Monthly discharge of Putah Creek at Winters, 1906–1907.

of producing electric current by power derived from Sierra streams, the greater part of the valley will in time be tapped by electric roads. Steam railways, forming a part of the Southern Pacific system, now traverse both sides of the valley, and the Western Pacific, which is

being constructed, will be accessible to the people living in the eastern part. In view, therefore, of the multiplicity of steam and electric railways, it is not likely that river transportation in midsummer on the Sacramento River above its junction with the Feather River

FIG. 11.—Monthly discharge of Cache Creek near Yolo, 1903–1906.

will ever become a factor in the development of this part of the State.

The writer believes that navigation should be maintained on the lower reaches of the river. He believes also that the diversion of

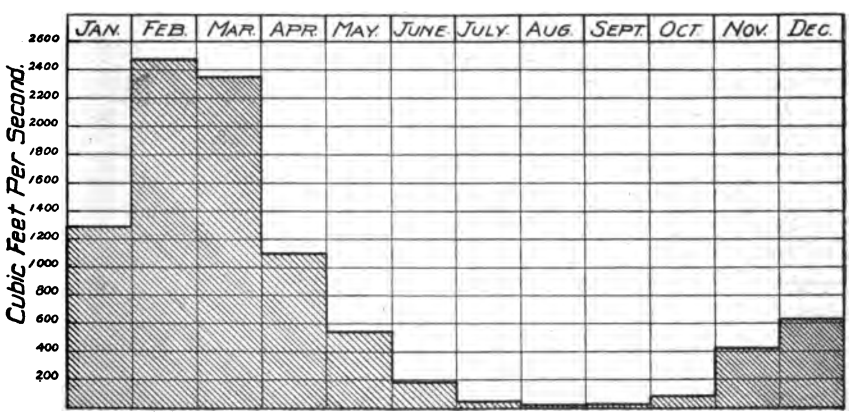

FIG. 12.—Monthly discharge of Stony Creek, 1901–1906.

water above and its application to lands bordering the main stream and its tributaries will not greatly impair water transportation below. A large part of the water used in irrigation in May, June, and July, when the river is high, is certain to return to the channel and increase the midsummer flow in the lower reaches. This return

water may more than compensate for the volumes diverted in months of low water.

In discussing the water supply of this valley it is well to consider the ground water. The quantity to be derived from this source in August and September is now limited, but as the irrigated area is extended, more ditches built, and more water wasted the amount of available ground water will greatly increase. Much of the land is flat and it will be impossible to apply water in irrigation without water-logging the low places. The removal of this water by means of wells and pumps should serve the double purpose of draining wet lands and of furnishing water for dry lands. With low rates for electric current and facilities for transmitting it to individual farms, the future possibilities in this direction would seem to be great.

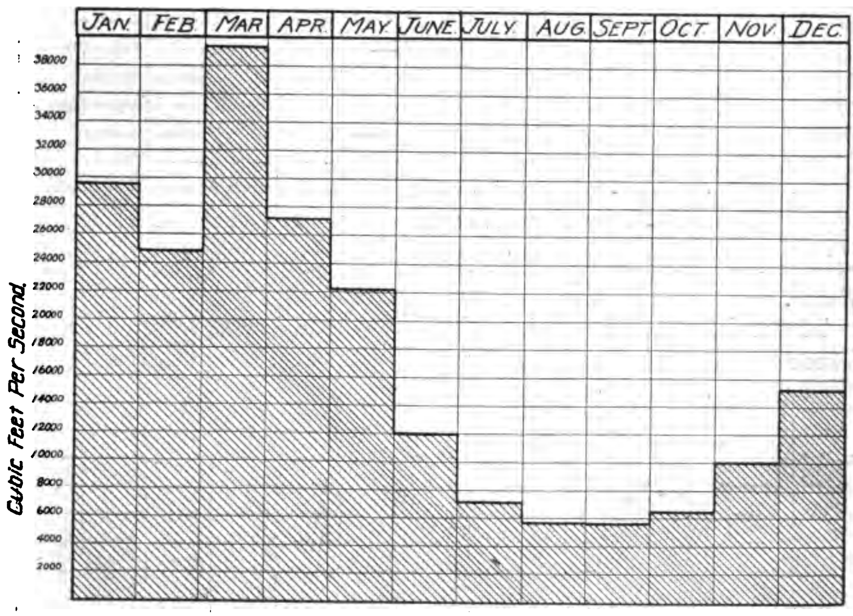

FIG. 13.—Monthly discharge of Sacramento River at Red Bluff, 1895–1896, 1903–1906.

THE DELIVERY OF WATER TO IRRIGATORS AND CONTRACT WATER RIGHTS.

In all the newer irrigation enterprises of the Sacramento Valley, the delivery of water to users has received little consideration thus far. The officers of these canals have been busy with construction and the settlement of the lands to be irrigated, and these matters have occupied the greater part of their time and energies. However, as these enterprises progress and more water takers are added, the necessity for delivering to each his proper share at the specified time will be keenly felt.

The rules and regulations which have been in use for some time in the older canal systems of the valley have been patterned after those of the hydraulic miners of an earlier day and are not well adapted to irrigation companies.

The manner in which water is delivered also depends on the nature of contract water rights. Under the Yolo County Consolidated Water Company, water is furnished for a stipulated annual rental and rarely is a perpetual right sold. Irrigators make application for a certain head of water for a given number of hours, and are

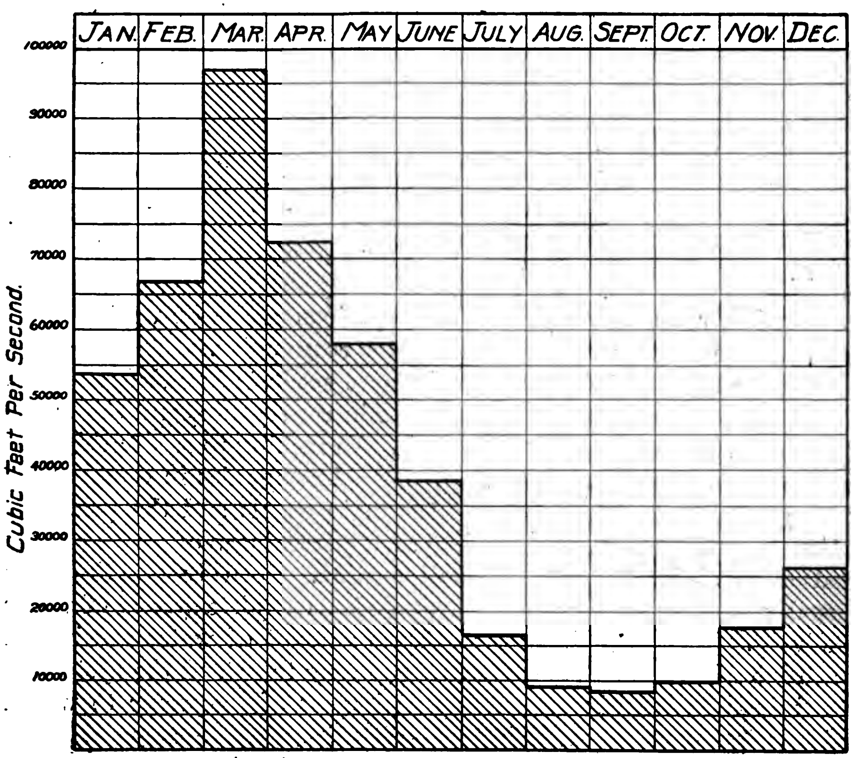

FIG. 14.—Available flow of water in Sacramento Valley.

charged for the water used at the established rate. This rate is fixed from time to time by the board of supervisors of the county, but the provisions of the ordinance with reference to the way in which water is to be measured can be complied with but rarely, and the quantity delivered is more or less guesswork. The present rates are $4 per foot in depth for twenty-four hours over a bulkhead 1 foot wide, with a velocity assumed to be 2 feet per second. This is usually taken as equivalent to $1 per acre-foot, and the head most commonly used is 12 cubic feet per second.

Under other canals perpetual water rights are sold at a fixed rate per acre and water takers pay an additional charge yearly for operation and maintenance. Under these contracts users are allowed the equivalent of a continuous flow of water of a definite volume for a certain number of acres. This volume is usually 1 cubic foot per second, and the area which it is intended to serve is 160 acres. The farmer who irrigates 16 acres would be entitled to a continuous flow of one-tenth cubic foot per second, but since this head is too small for irrigation he is given a much larger head for a correspondingly shorter period.

The lack of proper methods in both the measurement and delivery of water to users in the Sacramento Valley is common to all new systems, and this condition will be improved as the need for better methods becomes keenly felt. Too often, however, such improvements are long delayed, resulting in a useless waste of water, the water-logging of low places, and controversies between neighbors over the proper apportionment of the water in the canal or lateral. The early introduction of a just system of distributing water to those entitled to its use would do much to bring about a better and more economical use of water, lessen the injurious effects of waste water, and help to foster a better feeling in the community.

Among the first things needed is more accurate knowledge of the quantities of water diverted, the losses in conveyance, and the quantities delivered to the various laterals. In seeking to secure this, our agents have cooperated with several canal companies in establishing rating stations at the intakes of the main canals and the principal laterals, as well as in determining what percentages of water admitted are lost by seepage and evaporation. Such cooperation has usually been the beginning of a more or less complete system of water delivery. When a daily record of the amount of water flowing in each lateral is kept, it is comparatively easy to extend the system so as to include a fairly accurate measurement of the water to which each irrigator under the lateral is entitled.

In fixing charges for water under the irrigation systems of the Sacramento Valley two somewhat distinct factors should be considered. In the first place, it is worth considerable to a landowner to be within easy reach of a canal from which water can be obtained at reasonable rates. Almost without exception the construction of a canal and its successful operation enhance the value of land under it. This additional value and the privilege of taking water when it is needed are benefits bestowed on the landowner by the canal company, and some compensation for this should be made. This compensation is usually provided for by the purchase of water rights at fixed prices per acre. The other consideration is an annual payment

made by water users for the maintenance and operation of the canal system.

In the case of a canal company which first sells a water right for a definite piece of land and then collects an annual rental there is an opportunity for an equitable adjustment between the two; but when a company neither sells water rights nor provides in any way for their equivalent, the property owners under the canal do not assume any obligation to compensate the company for having furnished a water supply. The whole return to the company must come from charges for water. In a region of greater aridity, where irrigation is a necessity for the production of crops, such an arrangement might do, because farmers would be compelled to take water, but in the Sacramento Valley profitable crops can be grown without irrigation; and when men are free to purchase water or not as necessity arises, they may choose not to use any except in dry seasons. This uncertainty as to the income from water users and the reduction of revenue in wet seasons renders it difficult to meet the charges for operation and maintenance and pay the annual fixed charges.

THE USE OF WATER IN IRRIGATION.

A great deal of labor and considerable money for materials must be expended on the grain fields of the Sacramento Valley before irrigation water can be applied readily and efficiently. The cost of preparing the land, the building of farm ditches, and the structures required to control the large heads of water used are likely to exceed the average cost of the water supply. The work already done by the farmers along this line is not of the best, and but little can be taken as a pattern for other work. Many of the new settlers are unfamiliar with what is required, there is a scarcity of proper implements, and, in consequence, much of the land checking has been done imperfectly.

A general review of this kind is not the place in which to insert detailed descriptions of how land should be prepared and water applied. Attention is here called to the importance of this subject, and as a general guide to the irrigator the standard methods that may be used in this part of the State are shown in figure 15, which represents the irrigation tract on the university farm at Davis, Cal. This tract has recently been prepared for irrigation by H. I. Moore, acting under the supervision of the writer, for the purpose of carrying on cooperative experiments between this Office and the University of California. In examining this sketch the experienced irrigator will at once see that some of the checks shown are too small for farm use. The size was reduced for experimental purposes. Apart from this, a fairly correct idea may be gained of the standard methods of applying water to crops.

COOPERATION OF VARIOUS AGENCIES IN IRRIGATION DEVELOPMENT.

The agricultural development of the Sacramento Valley along right lines is perhaps California's most important problem. Here lies fully one-fourth of the total irrigable land within the State. In

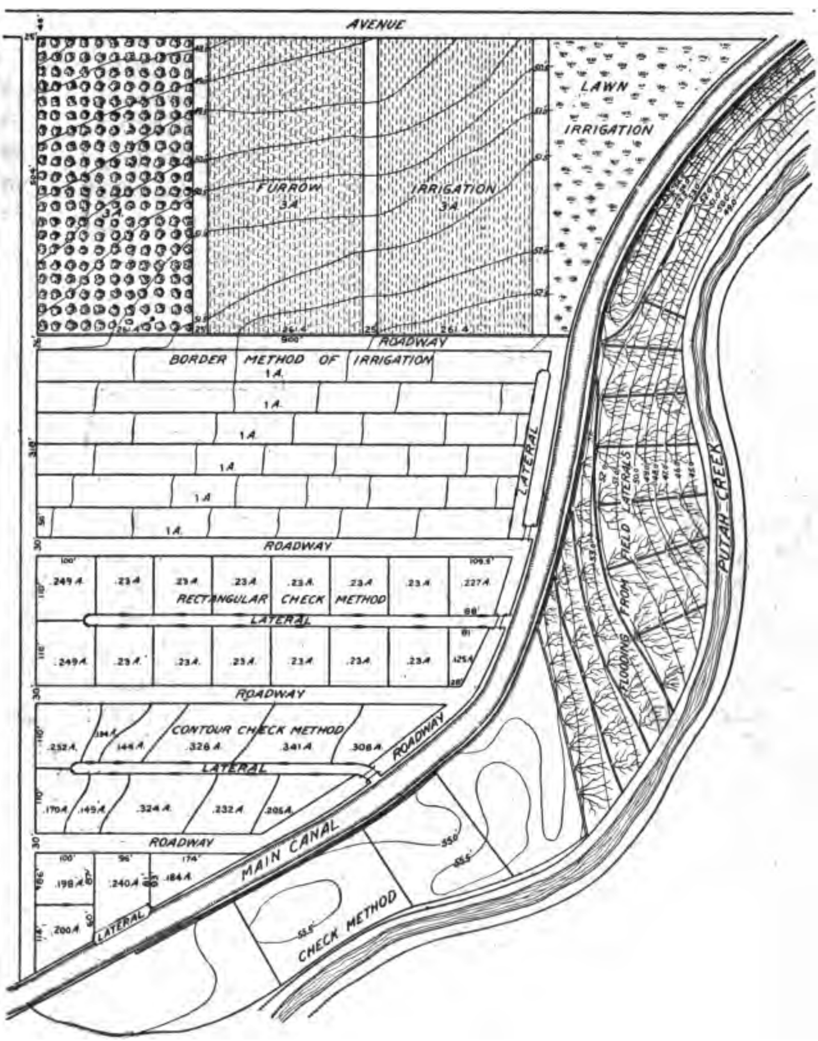

FIG. 15.—Plat of irrigated section of university farm, Davis, Cal., illustrating the different methods of applying water.

fertility of soil, climate, diversity of productions, transportation facilities, and markets it takes a first place. Under existing conditions and present methods of farming, probably not more than one-tenth of the revenue which these lands are capable of producing is

obtained. It is therefore extremely important to the State at large that these conditions be changed and a more profitable system of farming be adopted. But to bring this about will require a large amount of both labor and capital, and a brief discussion of the possible sources from which funds may be derived and the most suitable agencies to do the work may not be out of place.

The most important and valuable agency in transforming low-producing grain fields into profitable orchards, meadows, and vineyards is the labor of industrious settlers. In proportion to the number of acres cultivated, there have always been too few of this class. If they are given a favorable opportunity to establish homes and make a comfortable living, there should be no difficulty in getting settlers. The amount of work awaiting willing hands is enormous. It has been estimated that the cost of preparing the land for irrigation and building the farm ditches and the structures necessary for the control and use of water would average $14 per acre, or $35,000,000 for the entire valley. This vast sum will be doubled, if not trebled, before much return can be received from the more permanent and valuable crops which are destined to take the place of grain. All of this a sufficient number of thrifty settlers would in time accomplish, if given an opportunity. The chief difficulty lies in the fact that much preparatory work must be done before settlers can improve their holdings. The lowlands must be protected from destructive floods, and a water supply furnished for use in irrigation. The first, and in many cases the second, is beyond the power of the individual farmer. Only organization with large capital can control the flood flow of a river like the Sacramento.

In publicly discussing the best means of improving the Sacramento Valley men have frequently laid too much stress on some features and too little on others. For a couple of years there was an organized effort to induce the United States Reclamation Service to construct the works necessary to provide a water supply. The plan proposed by Mr. J. B. Lippincott, at one time supervising engineer for the Reclamation Service in California, was to divide the valley into a number of units, and to provide a water supply for each as means could be obtained from the sale of public lands in the manner provided for by the National Reclamation Act of June 17, 1902. The aggregate cost of all the units was estimated at $50,000,000. In support of this plan many went so far as to advocate that no reclamation or irrigation work should be attempted by private enterprise, but that all work of that nature should be planned and executed by the Reclamation Service in such localities and at such times as its officers should decide. There were others who sought to belittle the subject of river control and protective works and to magnify the benefits of storage

reservoirs as a means of preventing destructive floods. Engineers have gone so far as to advocate the diversion of a part of the waters of the Sacramento River and its tributaries during flood periods into mountain reservoirs, and in this way withdraw so much water from the natural channels as to lessen greatly if not wholly to prevent the floods. In advocating this plan they have failed to outline any practical way in which it can be done. It is not likely that storage reservoirs will ever be built for the sole purpose of preventing floods. The cost would be prohibitive. To have provided storage for the discharge of the Sacramento River below the mouth of Feather River for twenty-four hours on the 19th day of March, 1907, would have cost at least $20,000,000. But the flood lasted for four days with extremely high water both before and after this period. Furthermore, the rapid filling up of reservoirs with silt borne by flood waters would gradually reduce their capacity. It is therefore evident that for purposes of river control it will be much more economical to provide a passageway for flood waters by means of levees and channel excavation than to attempt to withhold the waters behind costly dams in the mountains.

If it is intended to build storage reservoirs to provide water supplies for the irrigation of lands in the Sacramento Valley and at the same time utilize them as occasion arises for the prevention of floods, the scheme is not feasible. There would be diverse interests that could not be brought together. The proprietors of the more elevated portions of the valley located near the foothills would want storage reservoirs solely for irrigation purposes; those in the lower portions for protection against overflow. One and the same reservoir could not well serve both purposes. The irrigators would never consent to take chances on a half-filled reservoir for the sake of keeping it empty awaiting a flood which might never come.

Since about two-fifths of the best land in the valley is liable to be flooded in extremely high water, it follows that for all the lowlands, at least, flood protection should precede irrigation. Also, since this undertaking is beyond the financial ability of the landholders, it is evident that both State and Government aid in the building of protective works should be sought. Having provided the means necessary for controlling the flood waters and with this problem out of the way, the work of providing an adequate water supply can be undertaken by both private enterprises and the United States Reclamation Service. Several million dollars have already been invested by corporations in the construction of irrigation projects described in this report, and about two-thirds of a million dollars has been allotted by the Secretary of the Interior for the irrigation of 12,000 acres of land near Orland, Cal., from water reservoired on Stony Creek.

These projects when completed, with others that have been built, will make a successful beginning, and there is no good reason why associations and irrigation companies should not work side by side in perfect accord with the officers of the Reclamation Service in developing the latent possibilities of the valley. The correct course for the people of this part of the State, therefore, seems to be to obtain all the assistance possible from both the State and the Nation in controlling the river and rectifying its channel, and in the meantime to encourage both the Reclamation Service and private interests to proceed, as they have done in the past, in the subdivision and irrigation of lands not subject to overflow.

SCOPE OF THE INVESTIGATIONS IN THE SACRAMENTO VALLEY.

Reference has previously been made to the rich soil, favorable climate, and heavy winter rainfall of the Sacramento Valley. It is believed these natural advantages have done much to retard irrigation development. For many years after this part of California was settled large yields of grain were obtained from the virgin soil without irrigation. As has been shown, these large yields, except in a few favored localities, can no longer be obtained, and much of the arable land is now farmed in this way with little or no profit to the owners, when all expenses, including interest on the valuation of the land, are deducted.

That irrigation has been of tardy growth is shown by the fact that in 1907 less than 1 per cent of the total arable land of the valley was irrigated. There is about 2,500,000 acres in the floor of the valley, and at present less than 25,000 acres is irrigated. This estimate does not include the Sierra foothill region, which will be the subject of a later report. The reports which follow include all the larger irrigation enterprises of the valley proper and embrace an irrigated area of about 22,000 acres, or 86 per cent of the total area at present irrigated.

The usual order of procedure was followed in the investigation of these enterprises. Sufficient data were first obtained for the preparation of a brief but accurate description of the chief features of each. Then followed an investigation of the various subjects pertaining to the use of water in irrigation. These embraced the conveyance of water and its delivery to users, character of water rights, and cost of water, seepage, and evaporation losses both in the channels and on the fields, duty of water under main canals and laterals and on individual farms, proper methods of preparing the land, methods of applying water, ascertaining the right time to irrigate, the removal of waste water, irrigated products, etc.

In a preliminary report of this kind it was thought best to obtain and present as much as possible of the irrigation conditions as they now exist, as well as a description of present practice. Upon this as a foundation future investigations of a more detailed character may be conducted in particular portions of the valley. The results herein embodied are but the beginning. In this extensive plain, with its cheap pasture lands and dry farms, is to be found a large share of the natural resources which will make it at no distant date, when its broad acres are properly cultivated and irrigated, capable of sustaining a vast population.

IRRIGATION UNDER THE YOLO COUNTY CONSOLIDATED WATER SYSTEM, YOLO COUNTY, CAL.

GENERAL CONDITIONS.

The Yolo County Consolidated Water Company, with headquarters at Woodland, Yolo County, derives its supply from Cache Creek, the largest Coast Range tributary of the Sacramento River. Yolo County occupies the southwest portion of the Sacramento Valley, and the location of the main canals and the larger distributaries, together with the irrigable lands under each, is shown on the accompanying outline map, figure 16. The area of Yolo County is approximately 600,000 acres. In 1906 the landowners paid taxes on 597,313 acres, which were assessed at $10,387,963. Of this area, about 350,000 acres is tillable, 130,000 acres grazing lands, and 117,000 acres tule and overflow lands. During the past ten years the area devoted to grain crops has varied from 200,000 to 240,000 acres. The most significant change in that time has been the substitution of barley for wheat, and more recently the raising of both for grain hay. In 1896, 160,000 acres was seeded to wheat and 16,000 acres to barley. In 1906 there were 84,000 acres seeded to wheat and 150,000 acres to barley. This change, if rightly interpreted, means that the soil, though still fertile, will no longer produce profitable yields of wheat. Soon it will not produce profitable crops of any kind without rotation, and the right kind of rotation can not be extensively introduced without irrigation. If this conclusion is correct, the future prosperity of Yolo County depends mainly on the extension of its irrigated area.

Fortunately for this part of Sacramento Valley, the water supply, if properly cared for, is abundant. Cache Creek resembles all the other streams of this valley in having a wide fluctuation between early spring and late summer, and were it not for the storage possibilities of Clear Lake, near the headwaters of the creek, little land could be watered in August and September. By utilizing Clear

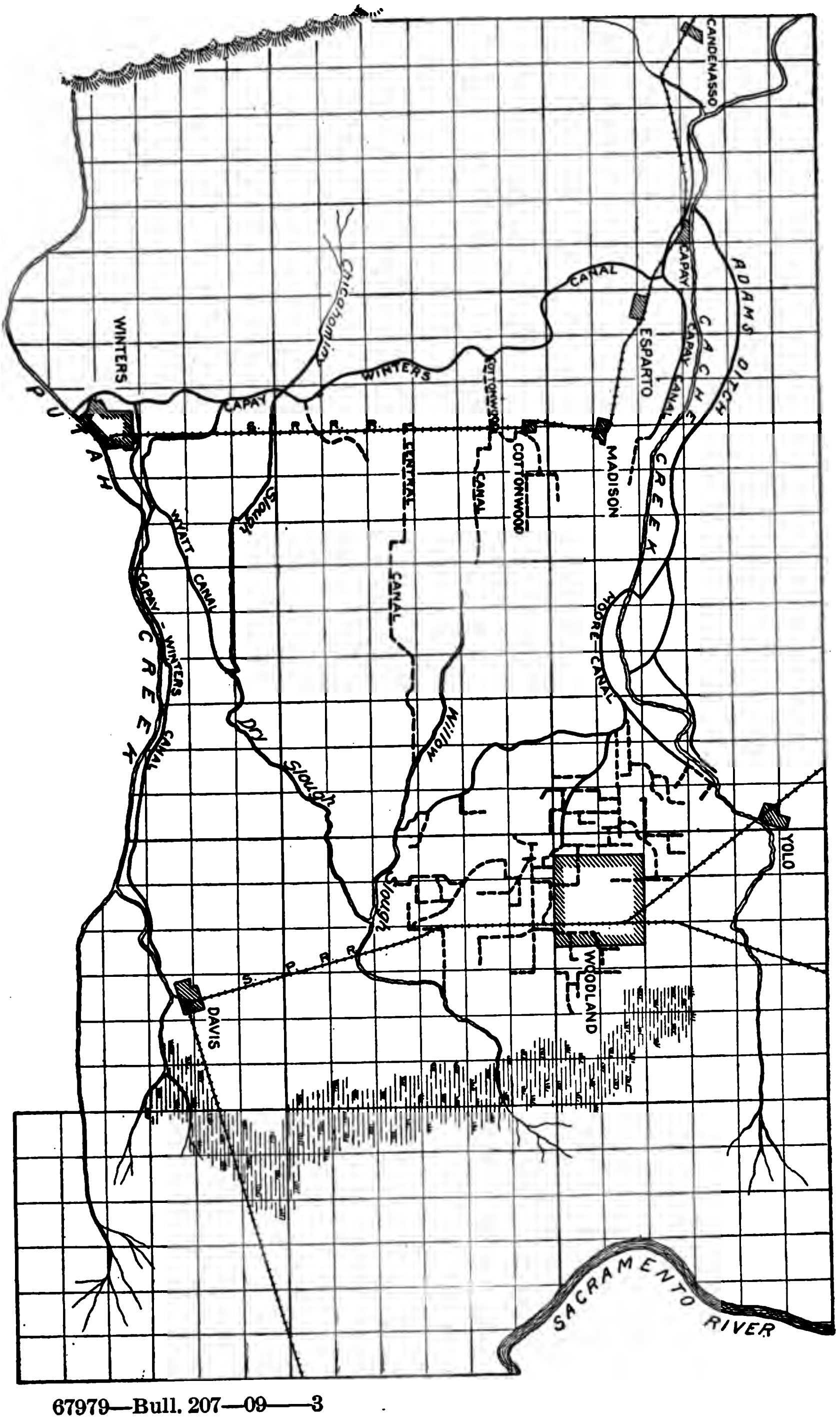

FIG. 16.—Map showing canals of Yolo County Consolidated Water Company.

Lake, which is one of the best natural storage reservoir sites in California, it will be possible to store the greater part of the flood flow for use in midsummer and to irrigate a large part of the 350,000 acres of irrigable lands in the county.

About 90 per cent of the 7,000 acres irrigated in 1906 and 1907 was in alfalfa. The extensive local dairy and stock-raising interests consume much of the alfalfa product, but a considerable amount is shipped to more distant markets. Orchards and vineyards generally are not irrigated, but the practice is increasing. There is some 10,000 acres of bearing orchards and vineyards in the county, comprising, besides raisin, table, and wine grapes, the following standard fruits: Almond, apple, apricot, cherry, fig, lemon, nectarine, olive, orange, peach, pear, plum, prune, and walnut. Many other fruits are grown in small quantities for the home market. Large quantities of potatoes, hops, and beans are grown on the bottom lands along the Sacramento River, which forms the eastern boundary of Yolo County. There is no apparent reason why the growing of these crops—together with sugar beets, tomatoes for canning, and other crops—should not be extended to the sedimentary uplands, especially under irrigation. All of the crops named have been grown successfully on a limited scale in the vicinity of Woodland.

The diversifying of crops has been hindered to a considerable extent by the holding of land in large areas by the pioneers and their descendants. Many sections of the finest loam, capable under irrigation of producing almost incredible returns, are thus used merely for grain growing or pasturage, the meager returns from which do not pay ordinary interest on the present value of the land. Only the fact that the owners of such tracts paid little or nothing for them or obtained them by inheritance from those who thus acquired them in early days, explains such an unprofitable use. It has been permitted to continue only by the further fact that these unimproved lands are assessed at a low valuation compared with that placed on improved lands of no greater intrinsic value. Happily, the more enlightened owners are coming to see the mistake of allowing their lands to lie relatively unproductive, and there is a growing tendency toward the subdivision of large holdings into the smaller tracts which are placed under irrigation. Coordinately there is going on a rapid extension of the irrigation system.

In 1900 the late J. M. Wilson, of this Office, made an investigation of the then existing conditions on Cache Creek with special reference to water rights, the results of which have been published in a previous bulletin of this Office.[a] At that time irrigation from Cache Creek was involved inextricably, as it seemed, in a maze of litigation.

---

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 100.

In consequence of the suits of James Moore against the Capay and Adams Ditch companies in 1882, a temporary injunction had been issued by the superior court restraining these ditches from taking water from Cache Creek pending the decision of these cases. As a result these canals ceased to be operated. The Cacheville Ditch, built to water lands near the town of Yolo, and the Clear Lake Company Canal, at the head of Capay Valley, had been abandoned on account of a judgment previously obtained against them by Moore, who claimed the right to more water than is normally carried by Cache Creek during the greater part of the irrigating season. Only the Moore Ditch remained in operation. In 1900 the suits against the owners of the Capay and Adams ditches still remained undecided. The Capay Ditch had been plowed in and the Adams Ditch was a wreck, irrigating only 20 acres of land and carrying a little water for stock. Eventually the owners of the Moore Ditch came into possession of all rights on Cache Creek.

CANAL SYSTEMS ON CACHE CREEK.

MOORE OR WOODLAND DITCH.

Work on the Moore Ditch was begun in 1856. At that time a temporary brush and gravel dam was built across Cache Creek and about 3½ miles of ditch was constructed for the purpose of irrigating some of the owner's private lands. Only a small tract was irrigated, however, and prior to 1864 no more than 3 cubic feet per second of water was actually used. In 1864 the ditch was enlarged and extended in two branches, the total length of which was about 9 miles. During the next few years some extensions were made by individuals and others by organized companies of farmers. From the time of first construction until 1881 the ditch was operated with temporary dams, which were carried away each season by the winter floods. In 1881 a more permanent wooden structure was placed across the stream, but this, too, was washed away after five years. Brush and gravel dams were resorted to again until the fall of 1903. At the death of James Moore, in 1884, he left the Moore Ditch under such restrictions that the trustees were unable without endless litigation to establish a satisfactory public water supply for irrigation. These conditions continued to exist until the early part of 1903, when by mutual consent those parties concerned caused the sale of the Moore Ditch, which, together with the Capay and Adams ditches, was bought by a new corporation known as the Yolo County Consolidated Water Company, which now holds practically all the available rights on Cache Creek.

On the Moore Ditch a new head gate was immediately installed at a cost of $1,000 and later in the fall a removable diversion weir and

permanent head gate were built at a cost of $11,000. The original system covered most of the irrigable lands and further extension has been very small. The West Fork has been extended 2 miles for a waste way into Willow Slough, and a few miles of farmers' laterals have been added. At present there is about 15 miles of main ditches, with 50 miles of laterals. Several old wooden diversion bulkheads have been replaced by substantial concrete structures and further improvements of this nature are being made as occasion arises.

The present headworks of this ditch, as stated above, consist of a wooden diversion weir and head gate, protected at the abutments by levees and wooden training walls extending above and below the weir on either side of the stream. It consists, in the first place, of a floor of 3-by-12-inch redwood planks extending 30 feet in the direction of the current. This is spiked to 4-by-12-inch joists, supported on four rows of square piling and one row of 5-by-12-inch sheet piling, all driven flush with the bed of the stream. The tongued and grooved sheet piling protects the upstream side from being undermined, and the floor between it and the superstructure is doubled and staggered for the same purpose. The superstructure, which is removed each winter and replaced in spring when the winter floods are over, is composed of removable flashboard posts mortised at the bottom into a 10-by-10-inch wale piece and braced by strong iron rods fastened to stout eyes bolted to the sheet piling and joists upstream from the posts.

The upper ends of the rods fit into slots in the tops of the posts and are threaded to receive nuts. The posts are aligned by screwing up these nuts. When the posts are removed, the rods are lifted out of the slots and dropped on the floor, where they remain under water throughout the winter. Each of the 4-foot openings between the posts is closed by six flashboards of 2-by-12-inch redwood, tongued and grooved. Figure 17 is a view of the weir from below, taken in September, 1906, with the flashboards all in place and when water had not long ceased to flow over the crest.

The head gate or bulkhead is a stout wooden structure framed of square piling and protected by sheet piling driven for 150 feet upstream. Retaining walls of 3-by-12-inch lumber extend through the levee, forming with a floor of the same material a 40-foot flume, founded on square piling, to prevent erosion of the ditch at the intake. The whole is strongly braced. Four openings, each 4 feet wide, admit the water, the flow being regulated by flashboards inserted in slots between the pilings. The head gate built lower down in the ditch to control the flow of water during the summer of 1903, as mentioned above, is of similar construction, and now serves as a "safety bulkhead" for use in case of accident to the actual head gate.

CAPAY AND WINTERS CANAL.

The old Capay Ditch, begun in 1877, extended from its intake, 3 miles above the town of Capay, some 7 miles in a general easterly direction, roughly parallel to the south bank of the creek. This was rebuilt by the new company in 1903 and 1904, and was enlarged for 4 miles from the head to a point near Esparto. From this point the ditch was extended in a general southerly direction to Winters, and thence along the north bank of Putah Creek eastward almost to Davisville. By this new ditch the canal system is enlarged so as to cover practically all of the irrigable lands in Yolo County south of Cache Creek.

The cross section is partly in excavation and partly in embankment, with berms at the ground level. The purpose of the berms is to pro-

FIG. 17.—Diversion weir of Moore Ditch on Cache Creek, September 6, 1906.

vide for cheap enlargement by avoiding the necessity of handling a second time the earth of the original embankment. In case of enlargement, only the berms would be removed. The total length of the main canal is 32½ miles. The bottom width at the head is 20 feet, and the depth 4 feet, with a side slope of 2 to 1. The grade varies with the nature of the country. For the first 4 miles from the head (the old ditch channel rebuilt) it is 2 feet to 5 feet per mile; for the next 10 miles, to the Graff ranch, 2.64 feet per mile. Thence to the waste way on the State University farm, near Davis, the grade is very irregular, and varies from 4 to 12 feet per mile. The designed capacity from the intake to the Graff ranch, a distance of 14 miles, is 200 cubic feet per second. Below the Graff ranch the cross section

is reduced as laterals are taken out, until at the end, near Davis, the capacity is about 80 cubic feet per second.

A temporary dam, renewed each year, is built up on the gravel bed of the stream, of brush mats, sacks of gravel, and loose gravel scraped in with scrapers. The brush mats used are 16 feet square and 3 to 4 feet thick. The brush, cut on the neighboring hillsides, is first wired into bales or bundles, and these wired together to form the mats. From 100 to 150 cords of brush are used in the dam. The mats are floated down with the current, held in position by ropes and gravel dumped on them until they sink into place. A foot depth of gravel is put on top of each mat, and one, two, or three tiers of mats used

FIG. 18.—Brush and gravel diversion dam at intake of Capay and Winters Canal.

as may be necessary to bring the dam up to the right height. The dam is begun at both banks of the creek and extended out into the stream, leaving a gap at first, to be closed later in the season when it becomes necessary to impound more water (fig. 18).

At the intake of the canal, on the south bank of the creek, a training wall or wing dam 100 feet long was built out into the creek bed in 1903 to divert the current and thus protect the bank along which the ditch runs for a quarter of a mile. This wall consists of two rows of piles 6 feet apart. Bed rock near the surface prevented thorough driving of the piles, which were therefore left projecting some 10 or 12 feet above the surface, strongly cross braced for mutual

support, and the space between the rows was filled with poles, brush, and bowlders to give weight and consequent stability. The outer 30 feet of this wall was washed away by the flood wave of May 6, 1906. The brush and gravel dam abuts on this wall, and an opening in the lower part of the wall, at the shoreward end, serves to admit water to the canal. There is no regulating device, the opening being closed in winter by spiking 2-inch planks across and throwing up an earth levee behind to keep out the flood waters. About one-fourth of a mile lower down, at a point where the canal leaves the creek bank, is a wooden gate used merely as a safety bulkhead to keep flood waters out of the canal in case of accident to the wing wall above. When the canal is in operation, water is turned in to the full capacity by extending the temporary dam to the necessary length, and the quantity of water carried down the ditch for use below is regulated by a waste way, discharging back into the creek 2 miles below the head of the canal. All water not needed for irrigation at any time is turned back into the stream through the waste way.

In connection with this canal about 40 miles of farmers' ditches have been built, of which the most important are the following, owned by incorporated companies of farmers whose lands they were built to water:

Cottonwood Ditch.—This ditch branches from the main canal 3 miles southwest of Madison. It is 6 miles long with several laterals, about 10 miles in all, covering probably 3,000 acres.

Central Ditch.—Central Ditch extends eastward 10 miles across the central portion of the county in almost a straight line, wasting into Willow Slough a short distance from the West Fork of the Moore Ditch. About 6,000 acres can be irrigated from it.

High Line Canal.—This canal takes water from the west side of the Capay and Winters Canal 2½ miles northwest of Winters, and runs along the edge of the foothills on the highest practicable line, thence descending to the town of Winters. Seven miles of its length was completed in the summer of 1906, but it is to be extended farther, and when completed will irrigate 1,000 acres of orchards in the vicinity of Winters.

Wyatt Ditch.—This ditch branches from the main canal east of Winters. It is 4 miles long and covers about 500 acres.

All of these farmers' ditches will be extended and numerous laterals will be built in the near future. They are capable of covering a much larger acreage than lies under them in their present form. Other farmers' ditches are also projected to connect with this canal. One, which is to water an extensive acreage north and east of Davis, is already surveyed. There was irrigated from the Capay and Winters Canal in 1906 an area of about 2,000 acres, with more being planted.

ADAMS DITCH.

In 1870 a ditch taking water from Cache Creek was constructed by some Chinamen to irrigate 20 acres of vegetable gardens on the D. Q. Adams farm, a few miles east of Capay. This was enlarged and extended in 1871–72, in 1878, and again in 1882. After these several enlargements and extensions the canal had a capacity at its head of nearly 250 cubic feet per second, but irrigated only 300 acres of land. In 1882 James Moore, considering that there was not enough water for all ditches taking water from Cache Creek, and assuming prior right, asked the courts for a temporary injunction restraining the Capay and Adams ditch companies from taking water from Cache Creek above his headworks and asked for an adjudication of rights. The temporary injunction was granted and the case has been pending since that time. The Capay and Adams ditches continued inoperative until 1903, when they came into the possession of the Yolo County Consolidated Water Company. The ditch was partially rebuilt by the present company and put in serviceable condition. The main ditch, together with the Hoppin branch, not including several miles of main laterals, is 22 miles long, a natural slough forming part of the channel. The bottom width of the canal at the head is 20 feet, top width 36 feet, and depth 4 feet. The ditch has a very variable grade, but will average 6 or 7 feet per mile.

The head gate of the Adams Ditch is of the same size and construction as that of the Moore Ditch. A temporary dam of the same construction as that of the Capay and Winters Canal is used to divert the water. The stream channel here follows the north bank, so that only a short dam is needed, but it is a difficult one to build, owing to the depth of the water, which in some seasons necessitates a dam 10 to 12 feet high.

A new wooden head gate, protected by wooden training walls, has been constructed at a cost of $3,000. Some 10 miles from the intake the company has built a waste way costing $500, which discharges back into the creek by a concrete drop just above the Moore Dam. By this means surplus water from the Adams Ditch is added to the supply available for diversion at the Moore Dam. Other recent improvements on this ditch are the concrete safety bulkhead half a mile from the intake, with waste way just above it, discharging back into the creek, and two concrete division bulkheads.

The beneficial effects of the policy of improvement and extension carried out by the Yolo County Consolidated Water Company are most apparent. With the assurance of water when needed, and under the stimulus of new canal construction, irrigation has risen in popular esteem in Yolo County, and has increased greatly. Besides the new

acreage brought under irrigation by the Capay and Winters Canal in 1905 and 1906, the acreage irrigated from the Moore Ditch and Adams Ditch has increased at least 25 per cent since 1903. The increase steadily continues, and will be further stimulated by additional improvements which are in prospect.

Aside from the plans looking to the utilization of the water-storage capacity of Clear Lake, which must ultimately be undertaken in order that the exceptionally fine natural possibilities of the Cache Creek watershed may be fully employed in the irrigation of the valley lands, the company has in immediate prospect substantial improvements to the present canal system in the shape of permanent dams or diversion weirs for the Capay and Adams ditches. Two plans are in contemplation—one to build a separate weir for each ditch; the other to construct a weir for the Capay Ditch only and to convey a portion of the diverted water across the creek at or near Capay to supply the Adams Ditch.

The water company now expends from $3,000 to $4,000 annually in constructing the temporary brush and gravel dams, which are destroyed by the winter floods, so that the erection of permanent headworks is necessary as a mere matter of economy. In addition, this will make it possible to supply water earlier in the season than it is possible to construct the temporary dams.

Another desirable addition to the system is the improvement and extension of the Clear Lake Ditch, which takes water from Cache Creek at the head of Capay Valley, above Rumsey. This, however, the water company does not wish to undertake except in cooperation with the landowners of the Capay Valley, whose lands would be watered from the ditch. At present the company leases the ditch to a few water users, who put in a temporary dam and operate about 2 miles of the ditch, watering a few orchards and alfalfa patches, not exceeding 150 acres. Properly developed and maintained, this ditch is capable of irrigating at least ten times as much land.

DUTY OF WATER UNDER MOORE DITCH.

The duty of water will naturally vary with the nature of the soil, the crop irrigated, the method of irrigation, and the skill of the irrigator. All that was attempted in the investigations reported below was to obtain some general knowledge of the amount of water used in the irrigation of alfalfa under the Moore Ditch. In each case current-meter measurements were made in the laterals at the margin of the field, thereby eliminating all losses in transit.

Water used on alfalfa under Moore Ditch, 1906.

Name of user.	Irrigation.	Date.	Acres irrigated.	Head used.	Water applied.	Depth of water applied.
				Cu. ft. per sec.	*Acre-feet.*	*Feet.*
H. J. Rasmussen	First	June 23	26	8.1	12.82	0.49
Do	Second	July 30	26	10.3	11.98	.46
Do	Third	Sept. 18	12	15.9	6.90	.58
E. C. Howard	First	June 9	8	10.0	5.00	.63
Roberts & Henley	do	June 14	29	13.2	20.58	.71
J. Henigan	do	June 16	20	20.7	18.33	.92
J. Kinchloe	do	July 11	30	8.1	16.20	.54
E. Clover	do	do	22	8.1	14.17	.64
—— Bedell	do	July 17	8	12.4	18.60	[a] 2.32
H. S. Button	do	Aug. 7	44	17.0	56.60	1.29
J. Harlan	do	Aug. 23	120	29.3	88.00	.73
G. Griffes	Second	Sept. 13	14	19.5	8.10	.58
Average						.82
Average excluding Bedell place						.69

[a] Very sandy soil.

It will be noticed that the above table refers only to single irrigations of the various fields, and in nine out of the twelve cases this was the first irrigation of the season. This usually requires more water than subsequent irrigations, because gopher holes are much more plentiful than later, many gophers being destroyed at the first irrigation, and because the land is pretty well dried out by the first two crops of the alfalfa grown without watering. This is especially true if the first irrigation is delayed until late in the summer, as frequently happens. In this locality comparatively few farmers grow alfalfa strictly as a hay crop. Most of them carry on dairying or stock raising in conjunction with raising alfalfa, which consequently is pastured a good part of the time. A common custom is not only to pasture the alfalfa in the winter, when even fields kept strictly for hay are ordinarily pastured, but to continue the pasturing until quite late in the summer. The stock is then taken off and the land irrigated for a crop of hay, and again for a second crop if the season permits. In this practice only two crops of hay are taken off the land, whereas from alfalfa kept solely for hay five crops will ordinarily be cut, two without the application of water and three with irrigation. In only one case was it found possible to measure the water applied during the entire season.

It is evident that with such irregular practice of irrigation—some fields being irrigated only once during the season, others twice, and others three times—only the broadest generalizations can be made as to the quantity of water used per year. It is believed that the measurements tabulated above, extending through the greater part of the season and including fields under different portions of the canal system, represent a fair average of the practice under the Moore Ditch for a single irrigation, and this is especially true if the

Bedell place be excluded from the comparison, as soil conditions on this place are abnormal. This conclusion is fortified by general observations throughout the ditch system.

Water registers were installed in three rating flumes on the Moore Ditch system at the beginning of the irrigation season of 1906. One of these flumes was located near the head of the main canal on the Wolfskill ranch, one each on the West Fork, or Montgomery Ditch, and the East Fork, or Rumsey Ditch, near the point of division on the Troop ranch. These flumes were carefully rated and the discharge measured for the season from June 9 to December 15. In 1907 an accurate survey of the lands irrigated was made and the acreage under each ditch determined. The gross duty of water is then based upon the actual amount of water measured divided by the acreage under each part of the system.

Gross duty of water under Moore Ditch.

Ditch.	Flow for season.	Area irrigated.	Average depth over surface.
	Acre-feet.	*Acres.*	*Feet.*
Entire system	21,926.9	6,957.8	3.15
West Fork	5,397.2	696.5	7.75
East Fork	10,656.5	4,312.4	2.47
North laterals	5,873.2	1,948.9	3.01

To the above should be added 6 inches of rainfall which occurred between June 9 and December 15.

This gross duty includes all losses due to seepage, evaporation, and leaky diversion weirs. The West Fork is used as a waste way for the entire system, and when the water is not being used upon the fields it flows through this ditch and is wasted into a near-by slough. This, with a large percentage of seepage, accounts for the low duty of water shown under this branch of the system. The highest duty of water appears under the East Fork, where over 4,000 acres of land were irrigated, with an average flow for the season of 28.88 cubic feet per second, or 150 acres for each cubic foot per second of water. The seepage losses found in a subsequent table must be considered in order to determine the amount of water actually applied to the land.

SEEPAGE AND OTHER LOSSES.

During the season of 1906 a number of current-meter measurements were made at different points on the Moore Ditch to determine the loss by seepage from different portions of the system. These determinations included the main canal and its main branches and four of the principal farmers' laterals.

Seepage and other losses from the Moore Ditch system, 1906.

Date.	Ditch.	Section.		Distance (miles).	Discharge at head (cubic feet per second).	Loss.		
		From—	To—			Cubic feet per second.	Per cent.	Per cent per mile.
July 31	Main canal	Head	Wolfskill flume	0.8	115.63	8.73	7.5	9.4
Sept. 8	do	do	do	.8	86.46	5.36	6.2	7.8
Aug. 1	do	Wolfskill flume	Troop ranch	4.0	112.93	4.26	3.8	.9
July 25	do	do	do	4.0	116.28	4.62	4.0	1.0
July 26	East Fork [a]	Troop ranch	Division bulkhead.	3.5	108.37	34.40	29.9	8.5
Sept. 8	do	do	do	3.5	44.10	8.83	20.0	5.7
July 19	West Fork [b]	do	Harlan ranch	5.0	65.95	41.39	62.8	12.6
Aug. 11	do. [b]	do	Montgomery ranch.	3.0	35.42	14.58	41.2	13.7
July 5	Hoy	Bulkhead	Bridge	.5	20.66	.82	4.0	8.0
July 17	Stringtown Lane [c]	Main canal	Blower ranch	2.0	24.69	7.68	31.1	15.5
July 24	South Fork [c]	do	Jackson ranch	1.0	29.93	4.92	16.4	16.4
July 5	Schoolhouse [c]	do	Miller ranch	2.0	30.40	15.09	49.7	24.8
July 5	Stringtown Lane [c]	Blower ranch	Bedell ranch	.5	17.01	4.60	27.0	54.0

[a] Rumsey Ditch. [b] Montgomery Ditch. [c] Farmers' Ditch.

The seepage losses in the upper portion of the system were very small, but for the most part the total losses were excessive. The first mile of the canal loses considerable water in the gravelly creek bed through which it flows. It is quite common, however, to find a high percentage of loss at the head of a system where the canal is built through the bottom lands. In the next 4 miles the seepage loss is remarkably small for an unlined canal. Two measurements with practically the same head flowing in the canal showed a loss of only 1 per cent per mile. This may be accounted for by several influencing conditions, the most prominent being the class of material through which the canal is built, the soil being a heavy clay loam. And again, herds of cattle and a great many hogs visited the ditch from adjoining fields throughout the summer of 1906 with the result that the constant tramping of the animals puddled the bottom and sides of the canal so that an almost impervious lining was created. The effect of the absence of the stock is shown in the measurements made by J. E. Roadhouse at the same points in the canal in July, 1907, when fewer cattle were in the pastures. The losses increased to 4 per cent per mile with the same quantity of water flowing in the canal.

Seepage losses from section of Moore Ditch, 1907.

Date.	Ditch.	Section.		Distance (miles).	Discharge at head (cubic feet per second).	Loss.		
		From—	To—			Cubic feet per second.	Per cent.	Per cent per mile.
July 10	Main canal	Wolfshill flume.	Troop ranch	4	126.7	20.9	16.5	4.1
July 30	do	do	do	4	62.57	12.5	20.0	5.0

The percentage naturally increases with the decrease in head; this is shown to a certain degree as we traverse the canals to the extreme branches or farmers' laterals. The measurements do not show an increase in a uniform ratio, however, owing to abnormal conditions. The ditch known as the West Fork shows a loss of about 12.5 per cent per mile. This ditch flows for the most part through an open, gravelly soil, which was evidently at one time the bed of Cache Creek, and presents an unsuitable material through which to build a canal.

The farmers' laterals show greater losses than any other portions of the system. The maintenance of these ditches receives, for the most part, little or no attention, and their channels are consequently in poor condition, foul with weeds, full of gopher holes, and with diversion weirs out of repair. As much as a cubic foot per second of water has been observed escaping from one of these defective diversion weirs. Under the company's form of contract, this amount of water if flowing continuously would irrigate 160 acres of land during the season. Should the water company adopt the policy of charging for the amount of water delivered into the heads of the farmers' ditches, as it is legally entitled to do under the county ordinance fixing water rates, the losses from these ditches would be felt keenly by the irrigators under them; and as the irrigators are the owners of the ditches, perhaps in that case effective measures would be taken to stop or at least to materially lessen the losses. Under the present liberal policy of the company, which charges only for the amount of water reaching the irrigator's individual lateral, as is done on the company's own ditches, the owners of the farmers' ditches have no incentive to keep them in good condition.

During the early portion of the irrigating season water is plentiful and losses are not felt, but later the stream flow lessens, water becomes more valuable and should not be wasted. Considering the comparatively short existence of the Yolo County Consolidated Water Company and its initial expenditures, and the condition of the land and crop values at present, the company would hardly be justified at this date in lining its canal with concrete or cement in order to overcome all seepage losses. A rather inexpensive lining of oil has been tried recently in other parts of the State, and has been found to be effective not only in checking seepage losses to a great extent but also in destroying the weed growth, thus restoring the canal to its original capacity.

The greatest losses on the Moore Ditch system occur in leaky diversion weirs. Substantial diversion weirs should be introduced as soon as practicable, the gates should be under the supervision of the ditch tender, and to prevent waste he should keep them under lock and key.

In August, 1907, J. E. Roadhouse made measurements on the Capay-Winters Canal for the determination of seepage losses, and obtained the following results:

Seepage losses from Capay-Winters Canal, 1907.

Date.	Section.		Distance (miles).	Discharge at head (cubic feet per second).	Loss.		
	From—	To—			Cubic feet per second.	Per cent.	Per cent per mile.
Aug. 9	Head	Capay	3.0	78.81	36.09	45.8	15.3
Aug. 9	Capay	Winters	15.5	42.72	7.20	16.8	1.1
Aug. 11	Winters	State farm, Davis	11.5	38.82	12.93	33.3	2.9

From the head to Capay this canal, not unlike many others, follows the old creek bed for nearly 3 miles and here loses a high percentage of water in the wash gravel. The loss by seepage from Capay to Winters, however, is very small, because the soil through which the canal is built is a clay loam, and the gates of the few diversion weirs that exist on the canal are made tight, allowing no water to waste. For a portion of the distance from Winters to Davis the canal is built through a lighter soil and along the bank of Putah Creek. The natural drainage through the creek bank has a tendency to increase the loss by seepage, which in fact is three times that in the upper portion of the canal system. Compared with other ditch systems the losses in the Capay-Winters Ditch, with the exception of that at the head, are not excessive. With the first 3 miles of the main canal lined with some impervious material, this system would be very efficient.

CANAL MANAGEMENT AND OPERATION.

Under the Moore régime a ditch tender was employed to apportion water to irrigators as called for, but so far as can be ascertained, no system was observed in the distribution, nor were any records kept. Such a state of things continued during the first years of the new ownership. The new company was occupied in the work of rehabilitating the old ditches and building the new one, and had not arrived at the point of improving the details of management.

In 1904 the following regulations were adopted, to take effect June 1:

1. All users of water will leave orders for same at the offices of the company.
2. No water will be furnished to any land where the bill for water for the preceding year has not been paid.
3. All users of water on branch ditches will be charged for same from the time it is turned in at the main ditch until turned off.

4. Water used on side ditches will be distributed in rotation, and all persons using water will be required to take same while it is in that ditch or wait until it is turned in for next general irrigation.

5. Interest will be charged on all bills not paid within thirty days.

6. Water turned on to any user will be charged for until notice is given by said user to turn off same.

7. Side or association ditches will appoint some member of their ditch company to look after and handle water, and keep time for same.

8. Parties ordering water will be charged for the same.

These rules were printed and copies furnished to water users, but with one or two exceptions they do not appear to have been enforced very rigidly. Water users had become accustomed to free and easy, go-as-you-please methods, and though such methods had never given them satisfaction, it proved none the less difficult to convince them of the advantages of systematic procedure. The water company wisely pursued a liberal policy, trusting to the educational effect of improved methods to bring about the desired changes gradually.

Early in 1906 the matter of improved management was taken in hand more definitely. The ditch tenders were required to make daily reports to the manager, showing all water delivered and labor and material used on the ditches, and also to take a receipt from each water user for the amount of water delivered to him. The following forms were adopted for these purposes:

Daily water delivery record.. 190 .

YOLO COUNTY CONSOLIDATED WATER COMPANY.

Users receiving water.	Time turned on.	Time turned off.	Total time.	Head, in feet and tenths.	Price.	Amount.	Crop irrigated.
....	....	....	....	....	......	....	......
....	....	....	....	....	......	....	......
....	....	....	....	....	......	....	......
....	....	....	....	....	......	....	......
....	....	....	....	....	......	....	......
....	....	....	....	....	......	....	......
....	....	....	....	....	......	....	......
....	....	....	....	....	......	....	......

Use this space for reporting labor or material used, etc.

....

....

No. ....

Delivered to ....

....feet of water from...o'clock...M.

......, 190 , to........M......

190 , making......hours.

Amount, $..........

.................., *Agent.*

No. ....

WOODLAND, CAL.,......, 190 .

Received of Yolo County Consolidated Water Co. from the.......ditch, ...feet of water, from.....o'clock ....M......., 190 , to.......o'clock....M......., 190 , making....hours, for which I promise to pay the sum of $..... with interest from thirty days after the date hereof, at the rate of one per cent per month, at Woodland, California.

....

Received payment,

....

Books of these forms were furnished to each ditch tender. The record is made in duplicate by means of carbon paper, the ditch tender retaining the duplicate in the book and turning in the original to the office. The water receipt, which is also a promissory note for the amount due for the water, avoids any dispute over the accounts of the office. It is negotiable, and the amount and interest are legally recoverable. When paid it is receipted by the water company and returned to the water user. The practice of the company at present is not to charge interest until after the first of January following the date of the receipt. The stub is retained by the ditch tender as a record of his part of the transaction, the receipt being turned into the office as soon as signed by the water user.

No adequate devices for measuring the quantity of water delivered to consumers have yet been installed on these canals. The county ordinance fixing the rate to be charged for water from the Moore Ditch reads as follows:

The board of supervisors of the county of Yolo, State of California, do ordain as follows:

SECTION 1. The maximum rate at which the owners of the Moore or Woodland Ditch shall sell and distribute for irrigation purposes the water appropriated by such owners and distributed by means of such ditch is hereby fixed at the sum of $4 per foot for the period of twenty-four hours, with the water flowing at the rate of 2 feet per second.

SEC. 2. The measurement of said water shall be made at the bulkhead in said ditch nearest to the place of actual use; provided, that where water is furnished through branch ditches not owned by the owners of said Moore Ditch, the measurement shall be at the bulkhead connecting the branch ditch with the said Moore Ditch. The measurements shall be made from the top of a weir 4 inches high constructed in the bottom of the bulkheads where measurement is made, and over which weirs such waters must flow.

SEC. 3. The patrons of said Moore Ditch shall be permitted to permanently fix in and affix to the bulkheads, where measurement is made, graduated scales, marked off into feet and inches, by means of which the depth of water flowing over the weirs therein can be detected at a glance.

Compliance with the terms of this ordinance, as was pointed out by Wilson,[a] is a practical impossibility under the conditions existing on the Moore Ditch and its branches, and this is likewise the case on the other canals in Yolo County. The differences in the grades, both in the main canals and of the branch ditches and the varying heads used, make it impossible under existing conditions to maintain any uniform velocity. Special adjustments for securing the required velocity over weirs, if practicable at all, could be made only after an exhaustive series of velocity measurements. Nothing of the kind has been attempted; the task would be a most difficult one. In practice the "foot" of the ordinance is interpreted to mean 2 cubic feet per second.

There still remains to the water distributer the problem of delivering the proper quantity of water for a "foot" or any multiple thereof. Prior to 1906 this was solved by the simple expedient of ignoring the velocity or assuming it to be always 2 feet per second, and calculating the head according to the cross section of the bulkhead through which the water was delivered. Thus for a 6-foot head, the size most commonly used, the ditch tender delivered 1 foot depth of water through a bulkhead opening 6 feet wide. It being impossible, for the reasons stated above, to deliver uniform quantities in this manner, the discretion of the ditch tender played an important part in satisfying the water users. When water was plentiful a generous allowance was made, and in the seasons of scarcity the ditch tender divided the water the best he could, with, of course, more or less dissatisfaction among the water users. Current-meter measurements in 1906 aided the ditch tender greatly in dividing the water among the irrigators, and if channel conditions in the ditches were improved and kept fairly uniform, flumes could readily be rated so as to serve all practical purposes in the guidance of the ditch tenders.

This would be perhaps the most satisfactory way at present of securing uniform and reasonably accurate water delivery under conditions existing on these canals. At some points weirs could probably be installed, and where they could be used they would doubtless be more satisfactory if properly constructed and maintained, but in many cases the grades are such that weirs could not be used without considerable expense in raising ditch banks and otherwise arranging for their proper installation. In justice to the water company, it should be stated that most of the branch ditches referred to are owned by associations of farmers, whose lands are irrigated by them and who are responsible for their condition.

Weed growth in the ditches is a grave source of embarrassment in the operation of the canals. As summer advances and the growth

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 100, p. 176.

accumulates it seriously impedes the flow of water and materially lessens the effective capacity of the ditches. Ditch grass (*Ruppia maritima*) is the most troublesome pest on the Moore Ditch and its branches, though a species of Potamogeton, another of the Pond-weed family, also abounds in the main canal. The growth is removed to some extent by dragging a heavy chain upstream by means of horses. This dislodges the weeds, which are allowed to float down to the nearest bulkhead and are there thrown out on the banks by men with pitchforks. Several miles of the main canal of the Moore Ditch were cleaned in this manner twice during the summer of 1906 at an expense of about $25 per mile for each operation, but, though great quantities of ditch grass were removed, much remained and the accumulation went on, so that the relief obtained was but temporary and the canal was soon as badly clogged as ever. The growth of this ditch grass is very rapid and the expense of cleaning is almost prohibitory, so it is proposed to try the effect of oiling the ditch bottom as soon as an opportunity can be had.

Old wooden bulkheads and other minor structures on the ditches are being replaced gradually by permanent structures of reenforced concrete. Improvements in the conveyance and distribution of water with a view to economy and exactness are earnestly desired, and will be made as fast as conditions will justify and suitable means can be devised.

COST OF WATER.

Up to July 24, 1906, no rights to water from its canals had been sold by the Yolo County Consolidated Water Company. On that date the company sold to the University of California a contract-water right on the Capay and Winters Canal for the university farm of 779 acres near Davis. The water right is for 1 cubic foot per second for each 160 acres, and the price paid was $5 per acre. The right is attached to the land and made to run with it. The contract also provides for an annual water rental of $1.50 per acre for the acreage actually irrigated in each year. The university is required to furnish to the company on May 1 of each year a statement of the number of acres to be irrigated that year and is to pay water rental for such acreage only. The company, on its part, contracts to furnish water for the specified acreage, but is not bound to supply any more in that year. As customary with such contracts, and much to the advantage of the water company, it is stipulated that in case of a short supply of water the university shall receive only such proportion of the water as its right bears to the aggregate rights on the canal.

This is the only instance in which a water-right contract has been entered into by this company. The Martinelli vegetable garden,

under the Moore Ditch, has an understanding whereby it receives the constant flow of a small head at a fixed rate per month, but all other water users on the three canals simply buy water as they need it and in such quantities as they desire. In times of scarcity stockholders in the company have a prior claim to water; other users take their chance one with another, and those located some distance from the main ditches are apt to go lacking. The water company is prepared to sell contract water rights on the same terms as those given the State University, but there is no demand for rights, irrigators apparently being satisfied with the present status.

Water from the Moore Ditch is sold under the terms of the county ordinance (p. 48) at a cost of $2 per cubic foot per second for twenty-four hours. The same rate prevails on the Adams Ditch and the Capay and Winters Canal. The head most commonly used is what is known as a 6-foot head, which amounts to 12 cubic feet per second, and costs therefore $24 for twenty-four hours, or $1 per hour. A flow of 12 cubic feet per second for one hour will cover an acre of land 1 foot deep, or, in other words, will furnish 1 acre-foot of water; consequently the cost of water, stated in the most generally acceptable manner, is $1 per acre-foot. According to measurements made in 1906 (see p. 42) the average net duty of water for single irrigations of alfalfa under the Moore Ditch is approximately 0.7 acre-foot, costing 70 cents per acre of land. Since two crops are ordinarily cut before irrigation, and each succeeding crop is irrigated but once, three irrigations suffice for five cuttings, which are all that can be had in most seasons. Thus the annual cost of water for alfalfa under this canal averages about $2.10 per acre, which is very reasonable when the value of crops is taken into account. Well-kept alfalfa fields in the vicinity of Woodland, with three irrigations, yield 7 to 9 tons of hay per acre, worth, at an average price of $6 per ton in the field, $42 to $54, the water cost being 4 to 5 per cent of the crop value. Many growers irrigate more cheaply than this, the amount of water depending largely on the thoroughness with which the land has been prepared for irrigation, the condition of the field laterals and the check gates, promptness in irrigating as soon as the previous crop is off, the skill of the irrigator, and the size of the irrigating head.

IRRIGATED CROPS.

As mentioned previously (p. 34), alfalfa is the principal irrigated crop of Yolo County. Most of the alfalfa is planted in the sedimentary loam belt, where it luxuriates in the deep, rich soil. Until recently alfalfa growing was practically confined to this belt, but experience with small fields here and there on the outside has shown that where the adobe lands lying between the sediment belt and the

mountains are covered with wash from the hills they are admirably adapted to this crop. Since the opening of the Capay and Winters Canal, the greater part of which lies outside the sediment belt, a considerable acreage of hill-wash land has been planted to alfalfa under this canal and its branches, and more is being planted as fast as water can be brought to it.

Generally speaking, bearing orchards and vineyards are not irrigated in this section, though there are exceptions to the rule. Newly planted vineyards are in some instances irrigated once or twice for the first two years in order to insure a good stand of vines and to promote thrifty growth. Several orchards on Cache Creek, notably the large Yolo orchard, have been irrigated more or less from pumping plants for a number of years to supplement the rainfall, the extent of irrigation depending on the amount of precipitation the previous winter. A few orchards are irrigated from the Moore Ditch also. The largest of these, the Byron Jackson orchard and vineyard of 160 acres, was laid out before planting in large rectangular checks for flooding. For several years this place has been winter irrigated only, the lessee, Mr. G. H. Hecke, believing that the best plan is to soak the deep sedimentary loam thoroughly in winter and then to conserve the moisture by good summer cultivation. His prune trees are sixteen years old, and recent experience has shown him that an additional irrigation as late in the summer as practicable increases the size of the fruit, which is a most important matter with prunes. The property has for many years had unusually good care, but it is to the regular use of water upon it more than anything else that Mr. Byron Jackson, the owner, ascribes the exceptional vigor and productiveness of the trees and vines.

On Putah Creek, in the early fruit region around Winters, the practice of orchard irrigation is on the increase since the completion of the Capay and Winters Canal has brought water within reach. Many orchardists in this locality have observed that copious rains early in the fall are followed by unusually good crops of fruit the following year. They have inferred that the moisture assisted the formation of strong, well-developed fruit buds, resulting in a good setting of fruit in the spring. Hence they have concluded to supplement the benefit of early rains by regular late summer or early fall irrigation. So far, comparatively few have been able to get water on their orchards, but the new High Line Ditch, taking water from the Capay and Winters Canal, will serve over 1,000 acres of orchards in the vicinity of Winters. The ditch is being built by orchardists primarily for orchard irrigation. The ability of orchard trees to bear repeated good crops is conditioned not as much upon special treatment at any particular time as upon general

well-being all the time. Nothing conduces more to this desirable state than the maintenance of a sufficient amount of moisture in the soil by judicious irrigation. It has been demonstrated over and over again that even orchards which have always been on the average fairly productive can be made much more profitable by irrigation. This is eminently so when the trees have attained large size and full productivity.

The failure of almond orchards on the Putah Creek loam to bear regular and profitable crops has long been a subject of complaint. The trees are of large size, make a heavy annual growth of wood, and bloom well, but the nuts drop off almost as formed. It has been suggested that this is due to insufficient soil moisture in the latter part of the season, causing imperfect development of the fruit buds, which might be remedied by timely irrigation. The views of growers on this subject, with regard both to fall and to summer irrigation, are indicated by the following from prominent orchardists of this section:

Messrs. Buckingham, Boyce, and Woolley, who have one of the largest and most profitable almond orchards in the vicinity of Winters, state:

> We have irrigated the past four seasons in September as soon as the crop was off. * * * We attribute much of our success to irrigation, as the trees have shown signs of needing it in the fall. Our soil is a sandy loam about 40 feet deep and it is about that far to water, and in seasons when the rainfall has not been heavy, particularly in the late spring, it seems to us that the moisture drops below the roots and the buds do not develop, i. e., they would lack strength to make a heavy set of nuts.

Mr. J. F. Agee writes as follows:

> I have practiced irrigation on 50 acres of almonds for the past ten years, and while the amount of the crop is not increased very much, the quality is much better, and the nuts larger and consequently heavier. The latter part of June or the first of July is the best time to water almonds, although I have watered in October to see if it would make the almond blossoms hold better. I could not see any better stand by October irrigation. Water applied the latter part of June or first of July will keep the trees growing and carrying a good foliage and they are not so apt to shed their leaves too soon, as is often the case on trees not irrigated. I believe irrigation pays, not from an increased yield but a much better quality.

Respecting the above, it is suggested that the summer irrigation, while improving the quality of the current season's crop, is not sufficient to insure proper development of the fruit buds for the following crop. The October irrigation, on the other hand, was without doubt too late to do any good. Probably a second irrigation in August or early September would have the desired effect on the fruit buds.

PREPARATION OF LAND AND APPLICATION OF WATER.

Prior to 1895 alfalfa land in this locality was laid out for irrigation on the rectangular check system, with checks of varying size according to the slope of the land and the fancy of the owner. The natural slope of the sedimentary loam is such that in most cases little or no grading of the land was necessary except that done incidentally in building the check levees. In some cases the checks were irrigated singly or in pairs from sublaterals, but in most instances the water was supplied from a single head ditch, and was run from one check to another across the field. Many instances of the second method are still to be found, most of them small tracts near Cache Creek, where the grades are relatively high. Contour checks are occasionally found where the fall of the land is rather heavy.

By far the greater portion of the alfalfa land in Yolo County is now irrigated by the border method. This system of checking was introduced into the district about 1895. Figure 19 is a plan of this system on a 40-acre field 1 mile west of Woodland. Objected to at first, this system rapidly became popular as soon as its advantages were perceived. These include cheaper preparation of land and economy in the use of water. This method of irrigation is especially adapted to lands with a slight fall and even grade, though, within limits, the amount of fall is not so important as regularity of slope. The field is divided by low, broad levees, or borders, into narrow checks running clear across, usually in the direction of the greatest fall. In this locality the checks are ordinarily about 50 feet wide and of any length up to 80 rods or more. After plowing, a field lateral or supply ditch capable of carrying 15 to 30 cubic feet per second, according to the size of the field, is first built along the highest portion, most commonly the highest boundary. The levees are then built by running scrapers at right angles to the direction of greatest fall, and dumping on the division lines at intervals of 50 feet or so. It is important that the scraping be done in such a manner as to leave the surface of the check as nearly level as possible between the levees. When being scraped the field presents the appearance of a field of hay raked into windrows. The levees are smoothed off and packed down by running a harrow and drag over them longitudinally. Occasionally the road grader is used for making border levees, but it does not give good results. It scrapes out a narrow strip on either side of the check, the earth from which is crowded up to form the levees. This leaves the middle portion of the check higher than the sides, so that the water tends to run down the sides, instead of spreading evenly over the check. The same result may be produced by the scraper, improperly used. Border checks should be level in cross section to irrigate well.

Water is admitted from the ditch at the upper end of the checks through a check box or bulkhead. It spreads out in a sheet between

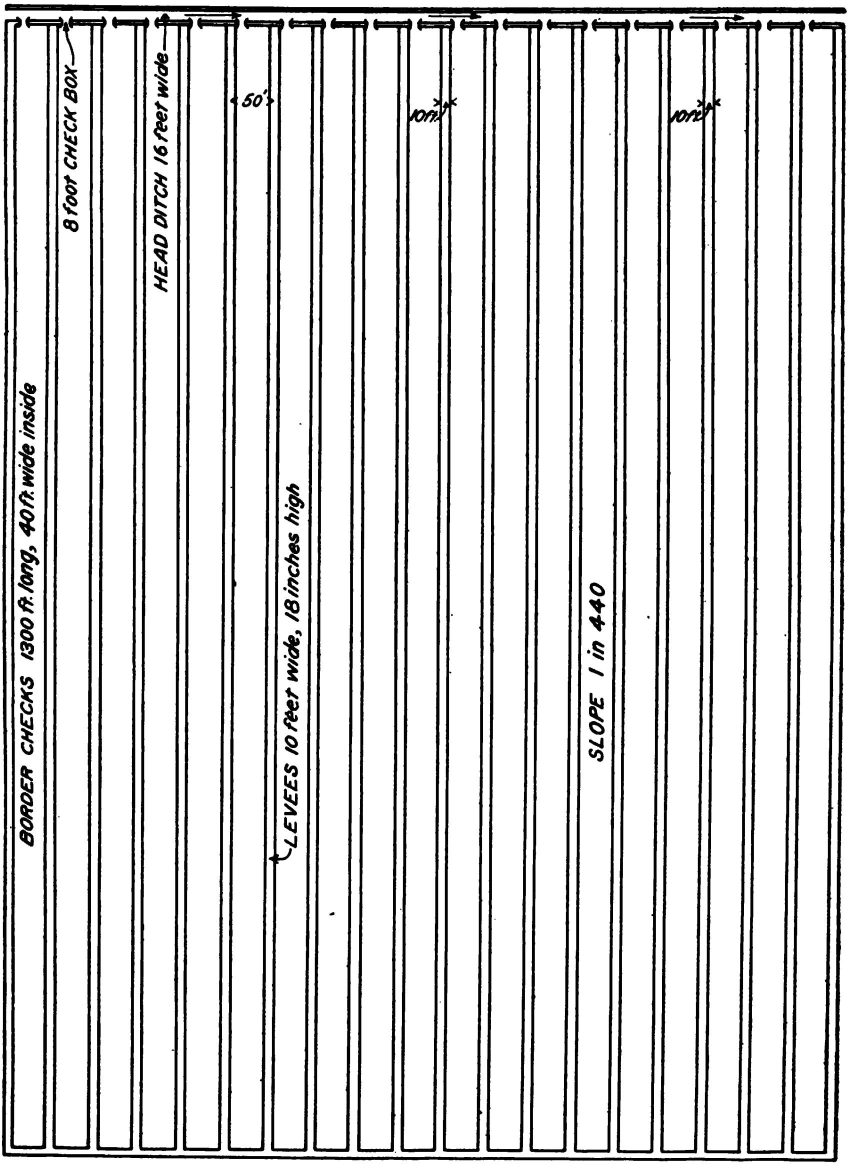

FIG. 19.—Border system for irrigation of alfalfa as used in Yolo County, Cal. The checks, 40 feet wide, are separated by levees 10 feet wide and 18 inches high. The head ditch is 16 feet wide with 8-foot check boxes for turning the water into the borders. The slope of the ground is 1 foot in 440.

the leaves and is allowed to flow down the check to within such distance of the lower end as experience has proven necessary. The

water is then shut off at the bulkhead, and part of the water already in the check flows on down and completes the irrigation. Good judgment is required to prevent waste of water, while at the same time securing a thorough watering of the check. Some means of drainage is usually provided at the lower end of the check, so that surplus water may be drawn off and not allowed to stand too long on the alfalfa, scalding it in hot weather.

Typical grades of alfalfa borders are 4 feet fall in 1,600 feet length of check, or 1 in 400, and 3 feet in 1,320, or 1 in 440. These represent a fair average of the grades on the best part of the sedimentary loam under the Moore Ditch. It requires a large head to force water rapidly over alfalfa stubble with these grades. For irrigating checks of such lengths heads of 20 to 30 cubic feet per second are used. In a field south of Madison the grade of borders runs as high as 1 in 100. With steep grades like this the checks must be made narrower than the customary 50 feet. In the case mentioned they were made 35 feet wide. Sometimes the grade runs less than 1 in 400, in fact some fields, or parts of fields, on the Woodland loam are practically level. Where this is so, the levees must be made higher than usual in order to maintain a head of water through the greater part of the length of the check, as pressure is necessary to force water through alfalfa stubble when the grade is slight. Well-made levees on land of ordinary grade are 10 feet wide and 15 to 18 inches high. Levees of this type offer no obstruction to harvesting machinery and yield almost as heavy a crop as the floor of the checks between them.

The cost of preparing land for border irrigation is $4 to $5 an acre, where the land requires no leveling except what is done incidentally in building the levees. This cost includes plowing, building ditch, and constructing levees. Check gates cost about $3 per acre, making a total of $7 to $8 per acre. Mr. P. N. Ashley prepared for alfalfa in the fall of 1906 70 acres of new land previously cropped to grain, at a cost of $225 for making levees and building distributing ditches. Men with four-horse scraper teams were paid $5 per day, and checked on an average a little over 2½ acres a day. These men were rather inexperienced. Good scraper teamsters will average 3½ to 4 acres a day in making levees. Previous plowing of the land with a steam disk plow cost $93, making a total of $318, or $4.54 per acre. Check gates were not included in this cost, but will amount to about $3 an acre additional. There was practically no leveling to be done on this place. Where leveling is needed the cost will run to $7 or $8 per acre and upward (exclusive of check gates) according to the amount of leveling needed. Seven to eight dollars appears to be a fair estimate for average land, or $10 to $11

with check gates included. This compares favorably with the cost of constructing the contour checks used in the San Joaquin Valley. The border method is now so much in favor that no other system is likely to be even considered at present.

The cost of seeding to alfalfa varies with the season, as in very wet seasons the land may have to be reworked several times before a chance is had to get the seed in. Reckoning one working of the soil, the cost per acre is approximately as follows:

Plowing	$1.25
Two harrowings	.50
Sowing	.25
20 pounds seed, at 15 cents	3.00
Total	5.00

Additional workings of the soil with disk and smoothing harrow would cost 75 cents to $1 each time.

Various types of check gates are in use. The commonest is constructed of wood on the general plan of the check box described and illustrated in a previous bulletin of this Office.[a] For heads of 10 to 12 cubic feet per second the opening is made 4 to 6 feet wide, 6 feet being preferable to 4 feet. For the larger heads of 20 to 30 cubic feet per second, used in irrigating very long checks, gates at least 8 feet wide are necessary. Short checks are satisfactorily watered with heads of 6 to 8 cubic feet per second. A check box extends through the ditch bank and is placed on the level with the floor of the check. Terra-cotta sewer pipe is similarly used for small checks, two or three 12-inch pipes being laid parallel to one another, and closed by wooden disks made to fit into the flanges on the upper ends of the pipes.

Wooden check gates are open to the objection of lacking durability, especially if poorly constructed. A much more permanent check gate of concrete, shown in figures 20 and 21, has been designed by Engineer P. N. Ashley and used by him on a number of farms. Mr. Ashley prefers to construct these without cutting the ditch bank until the bulkhead is completed. This preserves the stability of the bank, cheapens the construction by avoiding the use of wooden forms, and insures good setting of the concrete in damp ground. A trench of the proper size and depth is excavated with a post-hole digger of flattened shape, which removes a core of earth 4 inches by about 8 inches at each insertion, and does rapid work in loamy soil. The concrete is rammed into the trench thus prepared, and is reenforced with old baling wire dropped in from time to time. The bank is cut for the bulkhead opening at any convenient time after the concrete has thoroughly hardened. A flashboard gate of inch lumber

[a] U. S. Dept. Agr., Office of Experiment Stations Bul. 145, p. 32.

serves to close the opening. The cost of these bulkheads with an 8-foot opening is $4. Bulkheads of this size are used for long checks containing 1½ acres or more, making the cost per acre about $2.65.

Except in the case of short checks irrigated with small head, two men usually work together in irrigating alfalfa by the border method. A canvas dam is placed at the proper point in the supply ditch, and the irrigating stream turned into one or more checks, according to the relative sizes of the head of water and the check gates. It is desirable to use as large a stream as possible on each check so as to get over the ground quickly. One man remains near the upper end of the check to look out for the dam and for possible washing of the ditch bank; the other follows the water to the lower part of the

FIG. 20.—Concrete check gate on ranch of P. N. Ashley, near Davis, Cal.

check, looking out for the levee on either side of the check. When the water has flowed down so far that there is enough in the check to carry it clear through, the second man joins the first, they move the canvas sheet farther down the ditch, and proceed as before with the next check or checks. Sometimes two sheets are used, the second being put in position before the first is removed. With large heads of water this is a wise precaution. If the levees are in bad condition, more men may be needed to strengthen the weak places so as to retain the water, for which purpose stable manure is used ordinarily. The labor cost of irrigation by this method depends largely on the size of the head used. On land well laid off, with good check

gates and levees, two men can irrigate 20 to 40 acres in twelve hours, according to the size of the irrigating head, making the cost for each irrigation, under good conditions, 10 to 20 cents per acre, if wages and board cost $2 per day.

Vineyards are seldom graded for irrigation, as it is not intended to irrigate them beyond the first or second year. The young vines are ordinarily irrigated through a plow furrow on each side of the row, the even slope of the sedimentary soil permitting fairly efficient distribution by this means. Orchards intended to be irrigated are laid off in large rectangular checks. In years of short rainfall many orchards and vineyards, not watered at other times and not prepared for irrigation, are irrigated if water can be had. Free flooding has to be resorted to in such cases, and the water spread over the land as well as may be, without regard to evenness of distribution. Furrow irrigation, except as applied to vegetable gardens, berry

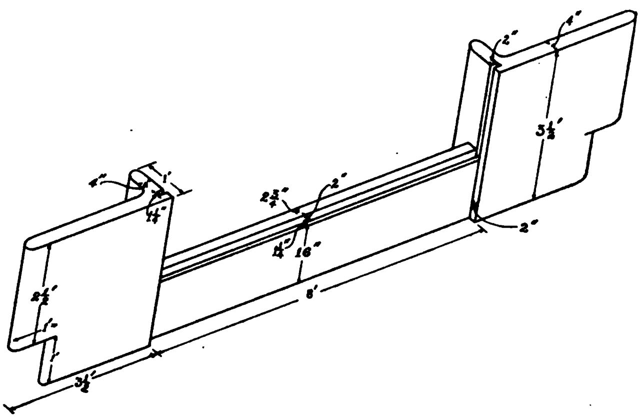

FIG. 21.—Isometric drawing of a concrete check gate used in Yolo County, Cal.

patches, and the like, is practically unknown in Yolo County. It is objected to on account of the necessity of careful grading of the land, which is much more expensive than large scale checking, and because of the amount of labor involved and the close attention required. The evolution of irrigation practice proceeds on much the same lines in Yolo County as elsewhere. Speaking generally, the present stage is that of the extensive use of water in large quantities with a minimum of labor and thought.

IRRIGATION UNDER THE CENTRAL CANAL IN GLENN AND COLUSA COUNTIES.

BRIEF HISTORY OF THE CENTRAL CANAL.

As early as 1865 surveys were made to determine the feasibility of diverting water from the Sacramento River to irrigate lands in the eastern part of Colusa County. It was not, however, until after

the passage of the Wright law in 1887 that anything definite was accomplished. On November 22 of that year the central irrigation district was organized by a vote of 271 to 51. On April 2, 1888, a vote was taken on the issuing of bonds to the value of $750,000 for the construction of the necessary works, which resulted in 190 votes for and 35 against. Twenty-year bonds, dated July 1, 1888, and bearing 6 per cent interest, payable semiannually, were issued. The bonds of $500 each, par value, are redeemable in installments at the end of the eleventh or any succeeding year until final maturity. Prior to July 10, 1889, $225,000 in bonds had been sold, and in October of that year contracts amounting to $290,000 were let for the excavation of a portion of the main canal.

The system, as originally planned, included over 60 miles of main canal with a bottom width varying from 60 feet near the head to 25 feet near the lower end, and a maximum capacity of 750 cubic feet per second. In this portion there was to be a uniform depth of 6 feet throughout on a uniform grade of 1 in 10,000. The distributaries as planned included about 200 miles of smaller canals, varying from 8 to 20 feet on the bottom and carrying water to depths of 2 to 4 feet. The intake is located on an arm of the Sacramento River near the boundary of Glenn and Tehama counties. The course for the first 6 miles is a few degrees east of south until Stony Creek is crossed at St. Johns. It then swings slightly to the west, and after traversing 5 miles in a southerly direction proceeds in a southwesterly course to a point 6 miles beyond Willows, where it again turns south and runs parallel to the foothills of the Coast Range as far as a small creek located nearly midway between the towns of Williams and Arbuckle on the Southern Pacific Railway.

The central irrigation district has been a failure. From the time of its organization in 1887 until 1905 no land was irrigated under it. To discuss at any length the causes of failure would not be germane to this report. Two years ago this Office published a report[a] of the Modesto and Turlock irrigation districts, in which the legal and constructional difficulties encountered were described, and the reader is referred to that publication. The Modesto and Turlock districts have attained a gratifying measure of success, and it is to be hoped that the Central Canal, too, will under its late reorganization be successful.

Many of the irrigation districts that were launched during the boom period which preceded the hard times of the early nineties had little or no water. This was not the case with the central district. It had the Sacramento River to draw from, the flow of which in the

[a] The Distribution and Use of Water in Modesto and Turlock Irrigation Districts, U. S. Dept. Agr., Office of Experiment Stations Bul. 158.

driest period is always far in excess of the needs of such a system. Nor was there any lack of irrigable land. The district as originally organized embraced an area of 156,550 acres. This did not include the large estates on the west bank of the Sacramento River, possessing soil of exceptional richness, or the larger area of less valuable lands lying beyond the terminus of the main canal. The Central Canal as planned could be readily extended to cover 250,000 acres. The failure was due to the active and bitter opposition of the minority of the landowners, protracted and costly litigation, inability to secure rights of way, mismanagement, and engineering mistakes.

By far the worst engineering mistake was made in the location of the upper portion of the main canal. From the intake on the Sacramento River to Stony Creek, a distance of nearly 6 miles, there is no fall whatever. As a matter of fact, there is a slight rise, for the sills of the gates at Stony Creek are 1 foot higher than those of the secondary gates near the intake. This precludes the possibility of conveying even one-quarter of the rated capacity of the canal, unless under a high head at the intake, and it is only during the rainy season, when water for irrigation is not needed, that a high head can be had. In years of average water supply there is not sufficient head at the intake during the month of August to force more than a small stream of about 25 cubic feet per second through the canal. The loss of the Stony Creek inverted syphon on the main canal shortly after it was completed, although not wholly due to faulty engineering design, was a severe blow to the district. This syphon consisted of seven semicircular tubes composed of wooden staves and steel bands laid below the bed of the creek. Owing, it is claimed, to insufficient anchorage, the first flood carried it away. It cost $53,848. Perhaps the greatest mistake made by the board of directors was in not securing the principal rights of way or options thereon before awarding contracts for large sums to construct a canal.

After considerable work had been done it was found that rights of way could not be obtained. In not a few cases the location was changed to avoid crossing particular holdings, thereby greatly increasing the cost. In other cases excessive prices for land were asked, and the opponents of the enterprise were not slow to take advantage of all opportunities that arose to delay progress and block the work. While a part of the bonds were sold, as provided by law, others were given to contractors in payment for work. This was considered illegal, and the opposition brought suit to show that the bonds were issued and sold illegally. This case is still pending. The opponents of the enterprise also brought suit to declare the organization of the district invalid, and in 1896 the supreme court declared it so, but the court refused to pass on the validity of the bonds. Not to exceed

$20,000 has ever been paid on interest coupons, both principal and interest, amounting to $574,000, are due July 1, 1908, and suits for the recovery of both are now pending in the courts of San Francisco.

LEASING OF CENTRAL CANAL.

The canal system in 1903, when it was leased for a nominal sum by the old board of directors of the central district to a corporation, included a main canal some 36 miles long, of which two sections of about 3½ miles each and a section at the head in deep cut of over 2,000 feet in length had not been excavated. The majority of the members of this corporation, which is known as the Central Canal and Irrigation Company, were interested in large tracts of excellent lands lying along the west bank of the Sacramento River, in both Glenn and Colusa counties, and their chief object in leasing and reconstructing the Central Canal was to obtain a water supply for these holdings.

One of the first undertakings of any magnitude on the part of the lessees was to construct a branch canal to conduct water to their lands. This canal taps the main canal about 12 miles from the intake and runs parallel to the Sacramento River for a distance of 20 miles. At the head it has a bottom width of 25 feet, a fall of 18 inches to the mile, and a computed capacity of 240 cubic feet per second, or sufficient to irrigate 40,000 acres. This branch has also about 40 miles of laterals of more recent construction. The lessees also completed the deep cut at the head by extending the main canal to the river and constructing substantial secondary head gates at a point about 2,000 feet below the intake. This was all done before it was understood generally that little water would flow through the upper part of the main channel at low stages of the river. To secure an additional head the company had the choice of three plans. One of these was to extend the canal up the river for a number of miles to a new intake; another was to build a diversion weir on an arm of the Sacramento River; and the third was to install a pumping plant and elevate the water drawn from the river to such a height that it would flow through the canal. The first of these remedies may be carried out in time, but after considering the matter it was learned that the costs for rights of way and excavation would be greater than the company cared to expend. The second was dependent on securing permission from federal authorities to dam an arm of a navigable stream, and as there was likely to be some trouble and delay in obtaining this permission it was finally decided to install a pumping plant. In 1906 the company obtained permission from Congress to use for irrigation purposes, subject to the supervision of federal engineers,

900 cubic feet per second from the Sacramento River. In the spring of 1907 a temporary flashboard weir was built in the head of the canal and a 44-inch centrifugal pump with siphon action, which discharges through a 48-inch pipe over 100 cubic feet per second, was installed upon the east bank. A diagram of this pumping plant is shown in figure 22. The pump is belt driven with a 225-horsepower electric motor; together with a short power line, transformers, and weir dam, the entire plant cost $25,000. It is estimated that a second unit of equal capacity could be installed for less than one-half this amount.

The plant was operated from July 12 to October 13, 1907, and in the following table is given the mean monthly discharge in cubic feet per second and the equivalent in acre-feet for each month the plant was run:

Discharge of pumping plant at intake of Central Canal during the season of 1907.

Time of operation.	Number of hours run.	Mean discharge per hour's run.	Total discharge.
		Cu. ft. per sec.	*Acre-feet.*
July, 18 days	410	96.2	3,251
August, 31 days	687	96.9	5,495
September, 30 days	694	101.0	5,781
October, 13 days	274	100.6	2,277

SEEPAGE LOSSES.

The greater part of the Central Canal traverses somewhat heavy soils and under favorable conditions the seepage losses would be small. When measurements were made in 1907 to determine the loss, less than 100 cubic feet per second was being admitted in a channel calculated to carry nearly eight times this quantity. As a result there was found to be a greater loss per unit of flow than would have occurred in a full canal. This loss in 11 miles was 37 per cent, or 3.4 per cent per mile. On the river branch the losses are exceptionally high, and as much as 50 per cent of the water admitted seeps back to the river through the porous soil. This is a loss that should be either greatly reduced or wholly prevented. In course of time it will pay to line this branch canal with Portland cement concrete. Meanwhile, a large part of the seepage might be saved by lining the canal with heavy crude oil. It has been suggested that the route of the canal be changed so as to pass through a more impervious soil, but the cost of a new right of way and of a new canal would make this seem unwise.

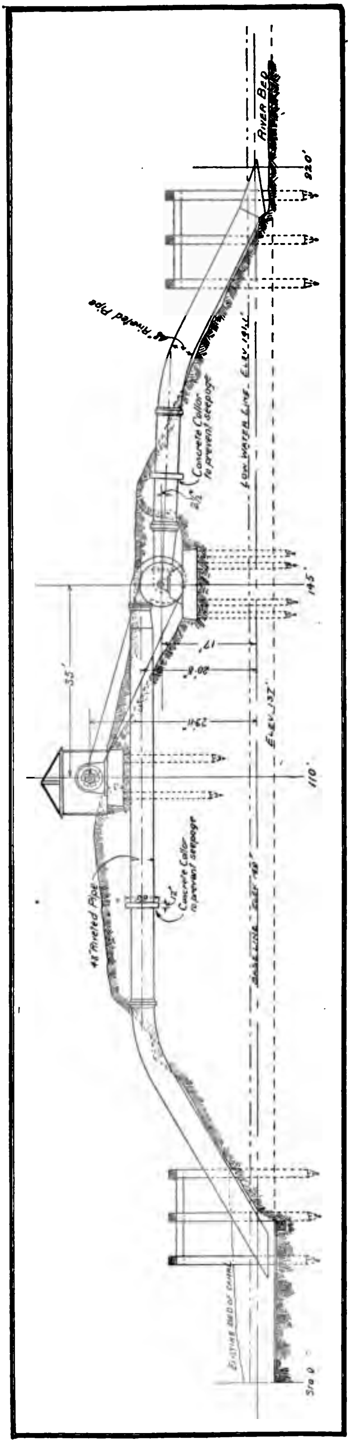

FIG. 22.—Section of pumping plant at head of Central Canal.

IRRIGATED AND IRRIGABLE LANDS.

In 1907 about 2,000 acres were irrigated under the system, and contracts have been signed for an additional 3,000 acres. This will make 5,000 acres for the ensuing season. The prices charged for water since 1905 when it was first used have varied, but the rate for the season of 1908 has been fixed at $3.50 per acre. The water contract states that at no time shall the duty of water be lower than 1 cubic foot per second for each 160 acres of land. Assuming that this amount of water is used continuously without loss from May 1 to September 30, a period of five months each year, it would cover 160 acres to a uniform depth of nearly 23 inches.

As has been stated, the central district embraces 156,500 acres that were susceptible to irrigation, and the completion of the river branch, or Colusa Canal, has added 40,000 acres more. The further extension of the main canal southward would increase the total area of irrigable land. It is therefore not improbable that over a quarter of a million acres could be irrigated from this system. This figure seems large in comparison to the 2,000 acres which were irrigated during the past season, but after nearly twenty years of expensive delays a beginning has been made, and there is good reason to believe that progress from now on will be quite rapid.

IRRIGATION FROM FEATHER RIVER UNDER THE BUTTE COUNTY CANAL IN BUTTE AND SUTTER COUNTIES.

GENERAL CONDITIONS.

This enterprise was started in 1904, and hence this report deals more with the possibilities of irrigated agriculture along Feather River than the past achievements of irrigation.

From the early occupancy of the Sacramento Valley its fame as a grain-producing area began to grow, and up to about 1885 the value of wheat land increased until it sold as high as $85 per acre, and averaged $65 to $80. The prevailing system was to raise two crops in three years, rotating wheat with oats or barley. Summer-fallow wheat was expected to yield 1,600 to 2,000 pounds to the acre, and winter-fallow about 1,100 pounds. As the yield began to fall off from year to year, larger areas came under individual control and cheaper methods of plowing and harvesting developed at such a rate as to offset the falling yields. But in the nineties both yield and price dropped by degrees until wheat farming was not very profitable. Reviving prices were unaccompanied by a return of former yields, and in 1903 the price of wheat land was about $30 to $60 per acre, and there was very little demand for it.

The present average yield is about 650 pounds, or five sacks (nearly 11 bushels), per acre. Even with the largest gang plows and combined harvesters, wheat raising is not now a profitable undertaking. Yet the price of wheat land is higher than its value as a crop producer, owing to a hope in the minds of some farmers that the failing crops are attributable to "bad years," or "wet winters," and that the former yields will return.

Prior to 1890 fruit raising had not attained much commercial importance in the section under discussion, though it was known that orchards could be raised on the lower lands without irrigation. When a pumping plant was put in in June, 1896, by Mr. A. D. Cutts to irrigate fruit trees, irrigation was looked upon as a rather doubtful experiment. The orchard lay on high land near the Feather River, and water was pumped for a quarter section of trees every year up to 1906, after which date a supply was obtained from the Butte County Canal.

Butte County Canal was started in the fall of 1904, the canal company handling only the engineering part of the enterprise, selling water rights under the canal at a uniform rate for all lands. Separate land companies were organized to colonize the irrigable lands, as the large holdings of wheat lands would have made the disposal of water rights to landowners very slow. Water was first delivered in 1905, so the present report covers about three years of irrigation under the system.

Water is diverted from Feather River about 10 miles above the town of Gridley. Below the point of diversion the river soon reaches a place where its fall is reduced to 3 feet or less per mile, making diversion nearly impossible. At the heading chosen the fall is much greater, and water is diverted through a deep cut by means of a low pile dam of the brush and rock type.

The drainage basin of Feather River above the canal head comprises practically all of Plumas County, which is largely mountainous, and the eastern half of Butte County. The winter run-off from the entire basin is very heavy, but during the summer months the flow is sustained by melting snows in the high Sierras. The low-water flow of the Feather River is so greatly in excess of the capacity and needs of this pioneer ditch that the question of water supply has not yet become urgent.

As the lands slope away from the river to the southwest, the canal skirts along the river on the crest of the alluvial bank, and the lateral system is all on the side away from the river.

THE CANAL SYSTEM.

The system of which the present canal is but a part contemplates the diversion of 500 cubic feet per second of water for the irrigation of 80,000 acres. The head gate is set back from the river in a 25-foot cut, its floor being 2 feet below extreme low water. It is heavily built of reenforced concrete and rests on a gravel foundation. At present wooden gates are used, raised by chain and block of 3 tons capacity operated from an overhead track. Owing to the difficulty of raising the gates in the spring with 20 feet of water in front of them, especially when banked with silt, needle gates are used in two of the openings and a check is built in the canal below the head gate by means of which the water can be backed up 10 feet against the lower side. For lowering the gates a jackscrew working against the caps of the superstructure is used. The steel used for reenforcement in the head gate was fence wire and old rails. The floor is reenforced with woven fencing. The superstructure is roofed over to prevent cracking in the hot sun.

The canal is 50 feet wide at the head, narrowing to 30 feet, and for 2 miles has no fall. From there to the first waste way, 9 miles below, the fall is 1 foot per mile, and below that 2 feet. The upper part of the canal was dug with a steam shovel and the banks are as nearly vertical as they will stand. The greater part of the canal has slopes of 1 on 1½. The extension into Sutter County is 22 feet wide and has 1 on 2 slopes.

The completion of the project will require the enlargement of the present line near the head and the building of a branch, from a point 4 miles below the head, parallel to and to the west of the present system.

The light grade of the country makes it necessary to run the laterals as high as possible, which requires the backing up of the water in the main canal until it is above the general elevation of the country. Hence checks are built in the main canal at frequent inter-

vals, and however little water is being used the water is kept high on the banks, making the canal virtually a series of level basins. The same is true of the larger laterals, checks being required to raise the water.

The head gate, two waste ways, and one culvert are of substantial concrete. All the checks and lateral head gates are of wood, well made, but subject to unusually speedy decay where they come in contact with the earth. Redwood is used as far as possible for the wet parts of structures. Bridges are simple trestle structures carried out to the center of banks without vertical abutments, as the shrinkage and swelling of banks soon displace a vertical curtain wall at the ends of a bridge. As soon as the demands on the canal and laterals are fully determined all structures are to be replaced with concrete as they require renewal.

The extraordinary flood which occurred in March, 1907, on the Sacramento River and its chief tributaries flooded the land adjacent to the intake and main canal. As a result large quantities of the material which had been excavated from the canal were washed into the channel, causing an obstruction which greatly reduced its carrying capacity. To remove this material as well as the river silt a suction dredge was designed and built. It consists of a 6-inch centrifugal sand pump driven by a gas engine, mounted on two scows. The suction end of the pump is provided with a rotary cutting head to loosen the compacted silt, and the suction pipe has a universal joint so as to be adjustable vertically and laterally. The discharge is carried out on the banks, and the excess water drained back into the canal. The device worked well during the spring of 1908, and solved a difficult problem.

DISTRIBUTION OF WATER.

The land under the Butte County Canal is divided into "colonies" of various sizes for facilitating settlement. The canal company, for a consideration of $10 an acre, contracts to deliver water to the highest corner of each tract of colony land at the rate of 1 cubic foot per second for 160 acres. The tracts are usually 10 or 20 acres. Having built the lateral systems the company makes over each lateral to the colonists thereunder, who are organized into a colony ditch company for the purpose. The maintenance of the lateral and the distribution of water therefrom rest entirely with the lateral ditch company. In these companies each acre represents one share of stock, and maintenance of laterals is assessed on an acreage basis. The engineers of the canal company handle all construction for the colonies, charging their time pro rata.

The annual charge for water in Butte County is $1 per acre. In Sutter County a separate ditch company, supplied with water through the Butte County Canal, disposes of water to users at the rate of $2 per acre annually. Of the 80,000 acres contemplated in the project, 30,000 are in Butte and 50,000 in Sutter County.

The project is developed in units, each unit being acquired, supplied with a lateral system, and sold to settlers as a separate integral step in the complete project. In May, 1908, about 5,000 acres were being supplied with water, the lateral systems being complete for all colonized lands. The supply of water in the canal being far greater than the needs of this area, no restrictions in the use of water and no attempts to measure it have been made. As is usual in newly irrigated districts, the loudest demand for water comes from those who have made the least or no preparation to receive it.

But this policy should not be carried too far, as wasteful use of water injures others besides the waster. In spring cultivation the recession of the ground water below the surface by natural drainage is the ruling factor on a large part of the lands, and with the normal depth to ground water small through the growing season, reckless and wasteful irrigation is certain to prove disastrous. If the duty assumed of 1 cubic foot per second for 160 acres, or 1 foot in depth every eighty days, is closely adhered to, injury from the rise of ground water may not occur soon. The important thing is to distribute water with such care that the rise of ground water may be taken care of with the least loss to agriculture.

SEEPAGE AND GROUND WATER.

There is no trouble from alkali under the canal, and very little from seepage. In one case water rose along the side of a slough between the ditch and the river, and this was thought to be due partly to irrigation on higher lands and partly to seepage from the canal, which cuts through porous strata near the place. A short drain ditch has relieved the difficulty.

For the great body of the land the only possible drainage is into sloughs flowing southwest into the Sacramento. These are saturated in the winter, and in order to be effective for spring drainage would require enlargement and cleaning out. They are not low enough generally to take underdrainage.

In June, 1907, the ground water stood within 6 feet of the surface over large areas, and after a few days' irrigating rose to within 3 feet of the surface, not only in swales but on average ground. Drainage is inevitable, and it is certain that eventually the lower lands will have to be given over to hay and crops that can resist water and that higher lands will have to be irrigated with caution and artificially

drained. Considerable areas of red lands lie above the canal, and their irrigation by pumping would be a great public benefit. Wells of large capacity can be obtained almost anywhere.

The need for drainage is coming to be well recognized, and drainage districts have been organized. Their purpose is to open up outlets for the removal of surplus water in the spring, and incidentally to drain those sloughs in which water rises near the surface because of irrigation. The problem of a place to waste water at the lower ends of laterals and below fields irrigated by furrows will be largely solved at the same time.

A large part of the lands in Sutter County is in a levee district for protection from flood water. The assessment for raising levees in 1907 was about $5 an acre. The lands are organized into a reclamation district under the laws of California, and levee work is in no way connected with the irrigation company.

PREPARATION OF LAND.

The soil under the Butte County Canal is a rather heavy alluvial loam of uniform character, with occasional streaks of gravel. It shades into heavier adobe to the west toward the Sacramento and into the red uplands to the north. Along the river are many stretches of recent silt deposits which are remarkably easy to work, even when rather wet. There is sand enough to make most of the soil easy to work if taken at the right time, but not enough to prevent caking if the irrigator fails to cultivate after irrigating.

The soil is undoubtedly deficient in humus, owing to long cropping with wheat with alternate summer fallowing, and its texture will greatly improve with the cultivation of alfalfa and other leguminous crops.

Many of the irrigators are wholly inexperienced in handling water, and every suggestion and assistance in the laying out of laterals and the leveling of land is given them by the engineering force. The detailed preparation of land is left to the irrigator himself.

For alfalfa most irrigators check their land in small rectangular checks. In an effort to save labor in applying water checks are made too small, five to seven to the acre. Those with more experience agree that two-thirds of an acre is a more convenient size. One reason for the prevailing use of small checks is that owners of valuable lands do not like to devote sufficient area to laterals to make them of large capacity.

Where well done, checking on average land costs $15 an acre. Too many try to build levees by borrowing material at either side of the bank, and make little effort to level the checks themselves. Because the country slope is only a few feet to the mile, it is not safe to assume

that a half-acre check has no high spots in it. Where land has been prepared for $5 to $10 an acre the results have not been satisfactory. Since alfalfa is put in to stay for several years, it pays to prepare the land with great care.

"Border checks," or long lands, are very satisfactory for alfalfa. The time given to the several operations in preparing 10 acres for the border system is shown below:

2-horse scraper, five days, at $4 per day	$20
3-horse leveler, four days, at $5 per day	20
2-horse harrow, two days, at $4 per day	8
2-horse disk harrow, three and one-half days, at $4 per day	14
Total	62

The usual rates are $1 a day per horse and $2 for men. This average cost of $6.20 per acre does not include check or border boxes to control the water as it issues from the head ditch; with this item added, the total cost would exceed $9 per acre. The checks are made level across, and water spreads perfectly over the surface when flooded down the slope. Two men can irrigate 10 acres a day when the land is laid out in this way.

Another experienced irrigator gives $10 an acre as the average cost of square checks, without boxes, having about two-thirds acre to a check. His estimate is based on two and one-half days on each acre, with a 4-horse scraper, which would cost $15 an acre at the prices given above.

Contour checks have been made and seeded to alfalfa at a cost of $10 an acre. One field was contoured for $5 an acre, material being borrowed from both sides of the levees. The small cost of such a method is its only advantage. A contour interval of 8 inches is about right for the light slopes.

IRRIGATED CROPS.

When we pass from dry farming to irrigation in Sacramento Valley, it is a change from a one-crop system to a system under which all kinds of crops are possible. For many reasons alfalfa is at present the most important irrigated crop.

Alfalfa is usually planted without a nurse crop in April or May, when there is moisture enough to bring it up and support it till large enough to irrigate. In case the soil is not moist enough, or expected rains fail to start the seed, it is very difficult to start alfalfa by irrigating it, as the ground, lacking shade, bakes hard and chokes the small plants.

Alfalfa is not only an easy and sure crop requiring little work, but it is vastly important here to restore humus and nitrates to the

soil and to supply fibrous waste to improve the soil texture. The extensive planting of alfalfa is urged by all who are familiar with conditions here and in San Joaquin Valley.

Owing to the heat prevailing during the growing season, irrigation before cutting is (or should be) more in favor than irrigation after curing. The first crop requires no water, the three or four succeeding crops requiring one irrigation each. When the fields are older the danger in irrigating after a cutting will be less, as the ground will be better shaded. Small checks are most in use, but long ones are recommended where the land has an even and sufficient slope.

Owing to the presence of native bur clover, there is an abundance of nitrifying bacteria in all the soils of the valley. On some lands gypsum has been used to advantage, at the rate of 200 pounds per acre.

Several small areas of sugar beets were planted in 1907, and in time beets may become a crop of great commercial importance. Most of the fields observed were planted as late as March, before the spring rains were fairly over, and as a result the ground caked around the young beets and by the time water for irrigation was available, about June 10, the ground was very hard. In one field the cultivator used for furrowing out for irrigation scarcely made an impression below 2 inches. The caked condition of the soil, of course, choked the beets, which grew misshapen and small. After irrigating it softened up, and might have been cultivated easily to a depth of 5 or 6 inches. Instead, it received only a shallow cultivation after two days, which was too soon for the wetter parts. The beets took a great start from their first irrigation, and cracks showed radially around each beet as a result of its expansion.

In general, the preparation of beet land for irrigation was faulty. The slopes are so light that wherever slight swales or rises occur the water leaves the furrows and spreads laterally. Flooding is fatal to young beets and injurious to half-grown beets where the soil tends to bake. As a natural result, the yields were not heavy, some fields being given over to stock. One 5-acre piece gave 12 tons per acre, the beets showing 19 per cent sugar. They were shipped to the factory at Hamilton.

The following suggestions are offered:

Run the furrows for irrigating beets down the greatest slope, even if diagonal, and grade the land enough to insure a continuous, though not necessarily uniform, slope down every furrow.

Deep fall plowing, exposure to winter rains, and thorough preparation of the seed bed in the spring by cross plowing and harrowing will prevent lumping as far as cultivation can prevent it. The ultimate remedy for a caking soil is to turn under alfalfa or other

legumes or manure, thus changing the texture of the soil by the addition of vegetable matter and humus.

It is essential to the expansion of the beet to cultivate deep in the center between the rows. A " bull tongue " is the proper implement, and not a wide shovel.

Two or three irrigations, beginning late in June, will be found sufficient.

All kinds of trees are irrigated to advantage, though figs and grapes are commonly thought to derive no especial benefit.

The leading fruits here will probably be the prune and peach. French prunes yield well, and some orchards regularly net $100 a year or more per acre. They stand any quantity of water, and, in fact, seem to thrive with ground water near the surface. Many orchards have to be propped to bear the fruit.

Peaches grow with great rapidity here, 2-year-old trees looking more like trees 3 or 4 years old. They require, or rather respond more generously to water than any other fruit crop. While the heavier lands raise the best peaches, the trees will not stand having water rise near the ground surface, and should be planted on the higher lands.

Oranges are not grown extensively, but are raised successfully in enough different parts of the project to warrant the belief that were the area increased to an amount that could produce carload lots they would prove commercially successful. They must have good drainage, and the ridge along the river or the higher red lands are best adapted for their growth.

Figs are not a commercially important crop as yet, chiefly because few of the best varieties have been planted. They grow luxuriantly, and require little care. Several small fig orchards were planted in 1908. Almonds, walnuts, and olives are all planted to some extent. Almonds are increased in size by irrigation, but do well without.

An experiment is being carried on by the Bureau of Soils of the United States Department of Agriculture to find a crop or crops suitable for the large area of adobe soil in Sacramento Valley. The experiment at present consists in planting 23 acres of rice and 5 acres of eucalyptus trees, alfalfa, and vetch. As the rice has to be flooded for long periods during its growth, the ideal soil for it has hardpan within 30 inches, which holds up the water, preventing underdrainage. The water requirements on such land will be reduced to that transpired by the plants and evaporated from the surface. The problem is quite as interesting to the irrigator as to the soils student, as the development of rice growing as an industry would require the development of a very large irrigated area not now contemplated under any project.

VALUE OF WATER.

The rainfall at Gridley for the past 24 seasons is shown by the following table, compiled from the records of Fred C. Moesth:

Rainfall at Gridley for twenty-four seasons.

Month.	1884.	1885.	1886.	1887.	1888.	1889.	1890.	1891.	1892.	1893.	1894.	1895.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
September	0.7	1.3	0.1	0.0	0.0	0.8	0.0	0.0	0.2	0.1	0.6	1.1
October	2.0	1,7	0.2	0.8	0.0	0.1	7.3	0.8	0.1	1.2	0.4	2.0
November	0.6	0.0	12.9	0.0	1.7	3.7	4.5	0.0	1.0	7.7	4.4	1.3
December	0.3	7.5	5.9	2.5	2.8	7.1	10.7	5.7	3.1	8.4	2.7	15.0
January	4.6	2.2	7.5	0.9	6.2	0.2	8.5	1.2	3.9	4.4	9.5	14.3
February	3.3	0.9	0.3	8.9	1.9	0.2	4.3	12.0	3.3	3.7	2.5	2.5
March	6.9	0.3	2.1	0.8	4.1	7.5	6.2	1.2	3.8	5.2	1.6	2.7
April	4.9	1.2	4.8	2.0	0.2	1.0	2.3	1.6	2.4	1.0	1.0	2.0
May	0.1	0.1	0.2	[a]0.0	0.3	3.1	2.8	1.3	3.5	2.0	3,1	0.7
June	3.4	0.5	0.0	0.0	0.5	0.3	0.4	0.1	0.0	0.0	0.7	0.0
July	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.4
August	0.0	0.0	0.0	0.0	0.0	0.0	Tr.	0.0	0.0	0.0	0.0	0.0
Total	26.8	15.7	34.0	16.7	17.7	24.0	47.0	24.1	21.3	33.7	26.5	42.0

Month.	1896.	1897.	1898.	1899.	1900.	1901.	1902.	1903.	1904.	1905.	1906.	1907.
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
September	3.4	0.9	0.3	0.4	0.0	0.3	1.0	0.0	0.0	3.8	0.0	0.4
October	0.6	0.4	2.6	0.8	7.1	2.2	1.7	2.6	0.2	3.7	0.0	0.0
November	1.1	4.4	1.2	0.7	5.8	4.0	3.4	3.5	5.4	4.9	1.6	1.3
December	1.7	4.6	1.7	1.9	4.1	2.0	1.9	3.4	2.7	4.4	1.3	9.7
January	14.6	3.4	0.9	7.3	5.8	5.1	1.6	3.6	1.2	5.4	6.6	5.4
February	0.4	6.0	4.3	0.0	0.8	6.4	10.9	1.3	5.3	3.9	5.9	2.3
March	2.4	1.9	0.0	7.2	1.6	0.6	3.7	7.3	8.8	4.0	8.4	7.7
April	6.7	1.1	0.2	0.1	1.8	3.3	1.8	0.5	1.4	1.4	1.4	2.1
May	1.5	0.3	1.2	1.3	1.2	0.5	0.9	0.0	0.3	1.8	3.7	0.4
June	0.0	0.3	0.1	0.6	0.3	0.0	0.0	0.0	0.0	0.5	1.5	0.8
July	0.0	0.0	0.0	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.0	......
August	0.2	Tr.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0	......
Total	32.6	23.3	12.5	20.4	28.6	24.4	26.9	22.2	25.3	33.9	30.4	30.1

[a] Dry from May 20 to November 28.

The maximum annual rainfall for the period was 47 inches, the minimum 12.5, and the average 26.67 inches. Thus, although there is no rain of any importance after May and the fall rains do not begin until September or October, the valley can not be called strictly arid. In fact, all kinds of crops besides grain have been grown without irrigation. Dry-land alfalfa cutting two small crops is said to produce better values than wheat. Prunes and peaches are raised in several parts of the project without water. Isolated spots along the river and elsewhere raise other crops without water.

But the value of water for irrigation is no longer a matter of dispute. Irrigation makes it possible to produce the best culture on all the lands. It improves the yield and the grade of fruit, and insures returns year after year. It makes the raising of alfalfa possible, and thus makes possible the restoration of the soil to new fertility.

The owner of the pioneer irrigated orchard in this section states that water doubles the value of a peach crop, enhancing quality as

well as yield; makes prunes grade five to ten points larger, with heavier yields as well, and greatly benefits oranges. His continuance of pumping for ten years for 160 acres of fruit prior to the building of a canal attests his belief in the value of water.

IRRIGATION ALONG STONY CREEK IN THE VICINITY OF ORLAND.

GENERAL CONDITIONS.

At the request of the officers of the Sacramento Valley Development Association and of the Water Users' Association of Orland, investigations were begun in the spring of 1906 under the Stony Creek Irrigation Company Canal in the vicinity of Orland, one of the most northern towns of Glenn County. The chief industry of Glenn County, as of other counties of the Sacramento Valley, has been the growing of wheat and barley without irrigation. For years both yields and prices were high and farmers were prosperous, but as prices fell and yields decreased on account of long-continued cropping without a change the industry ceased to flourish, and in many cases ceased to be profitable. The decline in grain raising is shown by the assessor's returns. In 1896, 145,000 acres was sown to wheat and 26,000 to barley. In 1906 only 35,478 acres was sown to wheat and 47,915 to barley. These figures show a falling off of 87,607 acres, or 51 per cent in the acreage sown to these grains.

Much of this county is better adapted to alfalfa and fruits than to grain, but fruits require irrigation, and in advocating the change one is met by the obstacles to irrigation ever present in this valley, namely, large land holdings, the cost of a water supply, the cost of preparing land for water and more valuable crops, and the prevalent skepticism regarding the value of irrigation.

The arable portion of Glenn County varies in elevation from 75 to 275 feet. The Central Canal taps the Sacramento River at an elevation of about 150 feet and crosses the southern boundary of the county at an elevation of 120 feet. By diverting water from the Sacramento River at a higher elevation and conveying it in a high-line canal the greater part of the arable lands of the county could be irrigated.

As far as the writer knows, no surveys for a high-line canal of this kind have ever been made. The landowners in the upper part of the county, in the vicinity of Orland, have always regarded Stony Creek as the only available supply. This stream rises in the Coast Range in the northwestern part of Colusa County, and after flowing in a northerly direction back of rugged hills for about half its course, makes a sharp bend and crosses Glenn County in a southeasterly direction, and empties into the Sacramento River. This stream has

been measured at Fruto, Cal., for a number of years by the United States Geological Survey, and the mean monthly flow at this gauging station for a period of six years is given graphically in figure 12 (p. 23). From this it will be seen that the available summer flow is extremely small, while the flood flow of February and March is quite large. It is also apparent that storage is necessary in order to hold back a part of the early spring flow for use in midsummer.

The East Park Reservoir site, one of several on Stony Creek, has been selected by the United States Reclamation Service, and work will soon be begun on the dam, which is intended to store 35,000 acre-feet of water for use on 12,000 to 14,000 acres of land in the immediate vicinity of Orland. The sum of $650,000 has been set aside for this project.

The general slope of the country about Orland is to the southeast, with a gradual fall of about 12 to 15 feet to the mile. Stony Creek has built up a delta extending from the foothills of the Coast Range to the Sacramento River, a distance of about 20 miles, with a maximum width of about 6 miles at the river. This " remade " land is mostly gravel, with here and there a small area of clay loam mixed with gravel. As the broad portion of this fan-shaped deposit is approached, one finds the rich silt loam of the Sacramento River bottoms. The subsoil in this gravel land is practically the same as the surface soil, with the exception of the slight amount of decayed vegetation and silt deposited on the latter.

The underdrainage is remarkably good until the bottom lands of the Sacramento River are reached. At 8 to 12 feet below the surface there is a stratum of wash gravel which carries the underground water well away from the irrigated farms. A free underdrainage is of great benefit in preventing the land from becoming water-logged and alkali-infected by the extravagant use of irrigation water. Stony Creek in the course of years has swept from south to north leaving a gravel belt between well-defined clay banks. Directly on the north of Stony Creek is found a heavy red clay loam. The gravel land has a more uniform surface than the clay land and hence is more easily and cheaply prepared for irrigation. There is a tendency, however, to apply a greater amount of water upon the gravel land than upon the heavy loam land. The underground water in the vicinity of Orland is found from 8 to 12 feet below the surface, depending upon the configuration of the surface of the land. The data concerning the change of position of the ground-water level since the beginning of irrigation are very conflicting and unreliable. In every case considered, however, the wells received their water supply from the gravel, whether 14 feet or 144 feet in depth. The water level was the same in dug surface wells as it was in deep-bored wells lined with

casing, indicating a hydraulic head common to all. Some surface wells have an inexhaustible supply of water, while others in the same neighborhood are easily pumped dry, yet both are in wash gravel. This may be accounted for by the presence of a deposit of clay, left by the shifting stream, which may be lying above the latter well, thus impeding the flow of water. The depth to water plane was measured in several wells. There was practically no change in the water level from June 14 to August 7. From August 7 to October 18 there was a uniform lowering of about 3.25 feet. This occurs every year, and later in the fall the water plane has been known to reach a depth of 16 to 20 feet below the surface.

CLIMATE OF ORLAND AND VICINITY.

The nights are warm during a portion of the summer, and the change between the temperature of night and day is not great. There is perhaps a little more humidity in the atmosphere here than in most of the southern counties of the State, owing probably to the presence of more bodies of water and a heavier precipitation. In the vicinity of Orland the rainfall averages 19 inches for the year. At Orland, July 8, 1905, the temperature reached 120° F., but the mean maximum temperature for the three summer months was only 98°. January 21, 1904, the temperature dropped to 18°. This had not occurred for twenty years, according to statements made by the older residents. The temperature rarely falls below 26°, nor does it remain low for any length of time. Lemon trees, which are very sensitive to cold, thrive and bear well in Orland and show no signs of any recent injuries by frost.

Meteorological records for Orland and vicinity are very meager and fragmentary. The following table gives about all the available reliable data obtainable from various sources pertaining to the temperature and rainfall at Orland:

Meteorological record, Orland, Cal., for 1903, 1904, and 1905.

Month.	Temperature, °F.							Precipitation.		
	Mean max.	Mean min.	Mean.	Max.	Date.	Min.	Date.	Total.	Greatest in 24 hours.	Date.
1903:								*Inches.*	*Inches.*	
January	....	....	45.2	63	24	28	11	2.27	0.68	....
February	....	....	45.2	65	24	28	14	1.70	1.20	....
March	....	....	49.7	72	24	33	3	4.20	1.57	....
April	....	....	56.4	83	24	34	9	.28	.28	....
May	....	....	....	....	....	....	....	....	....	....
June	....	....	71.9	102	26	50	9	T.	T.	....
July	....	....	76.8	103	4	51	22	0	0	....
August	....	....	78.6	107	8	52	16	T.	T.	....
September	....	....	74.2	107	1	60	16	0	0	....
October	....	....	....	....	....	....	....	....	....	....
November	....	....	....	....	....	....	....	....	....	....
December	....	....	48.8	65	1	30	5	2.70	2.00	....

Meteorological record, Orland, Cal., for 1903, 1904, and 1905—Continued.

Month.	Temperature, °F.							Precipitation.		
	Mean max.	Mean min.	Mean.	Max.	Date.	Min.	Date.	Total.	Greatest in 24 hours.	Date.
1904:								*Inches.*	*Inches.*	
January [a]	53	25	39	81	25	18	21	0.27	0.27	17
February	60	39	50	76	2	30	9	3.96	.77	12
March	60	42	51	77	31	31	25	6.36	2.36	10
April	73	47	60	91	11	35	22	1.87	.90	19
May	87	54	70	106	21	33	26	T.	T.	17
June	95	63	79	112	27	50	15	T.	T.	1
July	97	63	80	108	23	54	11	T.	T.	15
August	101	62	82	111	6	52	23	T.	T.	23
September	91	58	74	110	6	52	26	3.08	2.18	23
October	76	51	64	92	2	40	31	2.60	.80	11
November	64.5	44.5	59.5	75	9	36	21	1.96	.91	27
December	53	37	45	61	17	30	17	3.40	2.21	30
1905:										
January	55	40	48	66	16	30	12	7.67	1.71	24
February	63	42	52	78	24	30	14	2.82	1.44	1
March	67	46	57	83	6	32	30	4.43	1.10	12
April	77	48.5	63	88	23	37	19	.65	.41	15
May	79	52	66	101	15	43	10	2.23	1.11	7
June	92	57	75	103	10	48	4	.39	.35	8
July	102	63	83	120	8	45	27	0	.00	....
August	100	59	80	112	8	43	3	T.	T.	21
September	92	57	74	104	21	48	28	T.	T.	24
October	81	48	65	95	3	41	17	T.	T.	7
November	68	41	54	83	7	28	28	1.45	1.21	29
December	56	36	46	69	10	27	23	1.26	.58	27
Mean annual:										
1903	....	....	61	107	Aug. 8	28	Jan. 11	....	2.00	Dec. —
1904	76	49	63	112	June 27	18	Jan. 21	23.90	2.36	Mar. 10
1905	78	49	64	120	July 8	27	Dec. 23	20.90	1.71	Jan. 24

[a] Total precipitation for month, 0.72 inch. The other data for January, 1904, cover the 11th to the 31st only.

Climatological data for Orland, Cal., 1897–1901.

[Elevation, 254 feet.]

Year.	Temperature °F.					Precipitation (inches).				Rainy days.	Sky.			Prevailing direction of wind.
	Mean annual.	Highest.		Lowest.		Total for year.	Greatest monthly.	Month of greatest precipitation	Total snowfall.		Clear days.	Partly cloudy days.	Cloudy days.	
		Degrees.	Date.	Degrees.	Date.									
1897	64.9	110	Aug. 19	27	Dec. 22	14.14	4.01	Feb...	0	....	......	......	......	
1898	65.6	118	Aug. 12	26	Jan. 12	7.93	3.64	Feb...	0	25	229	4	132	N.
1899	64.4	115	July 19	26	Feb. 4	22.41	6.98	Jan...	0	65	195	3	167	N.
1900	62.0	112	...do....	26	Dec. 31	18.40	4.61	Nov ..	0	60	200	1	164	N.
1901	65.0	116	Aug. 3	24	Jan. 1	17.86	5.14	Feb...	1	40	......	......	......	

With the accompanying curves (fig. 23) we can compare very readily the mean monthly temperature with the mean maximum and mean minimum temperatures of the same month, noting the departure from the normal. The mean monthly temperatures were obtained from records for 1903, 1904, and 1905. The mean maximum and mean minimum temperatures were obtained from records for 1904 and 1905.

Figure 24 is a graphic representation of the mean monthly precipitation at Orland for three years—1903, 1904, and 1905. The mean annual precipitation for these three years was 19.82 inches. The wet season begins usually about the middle of September and ends about the middle of May. This leaves about four months of the year with practically no rainfall. The season of 1906 was exceptionally late with rather heavy precipitation, as shown by the Southern Pacific records.

Monthly precipitation at Orland, Cal., in inches, 1905–6.

Year.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Total.
1905......	T.	T.	1.44	0.94	......	......	......	......	......	......	......	......	......
1906......	......	......	......	......	5.70	3.30	9.11	1.49	1.75	0.55	0	T.	24.28

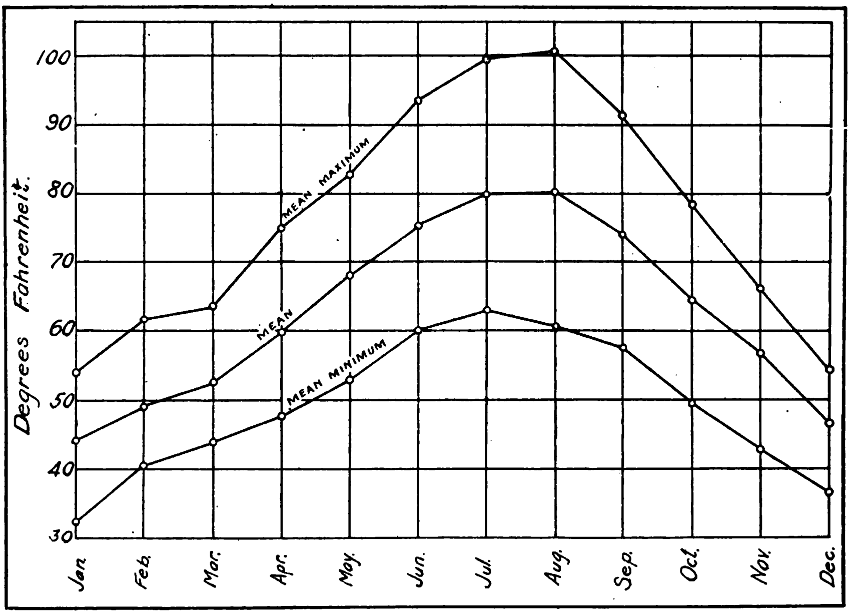

FIG. 23.—Mean monthly temperature for 1903, 1904, and 1905 at Orland, Cal., with mean monthly, maximum, and minimum for 1904 and 1905.

The general movement of the air is either north or south. In the winter the north winds tend to lower the temperature, and in the summer winds from the same direction seem to make it warmer. A wind from the south in the summer cools the atmosphere, and clouds are nearly always formed.

WATER SUPPLY.

Water for irrigation is supplied by the Stony Creek Irrigation Company, a local company incorporated January 20, 1888. The point of diversion from Stony Creek is 9.5 miles northwest of Orland, in the southern part of Tehama County. The company claims the right to 100,000 miners' inches of water from Stony Creek, but there never has been occasion to divert more than a small fraction of this amount. Up to the present time the water rights have never been adjudicated. Several actions have been commenced by and against the company, but none of them has gone to judgment.

The canal system of the company consists of 9.5 miles of main canal, 4 miles of main laterals, and 4 miles of sublaterals. The canal is very much eroded for the first 4 miles, leaving it about 8 feet wide on the bottom and 6 to 8 feet deep. The lower 5.5 miles is partially filled

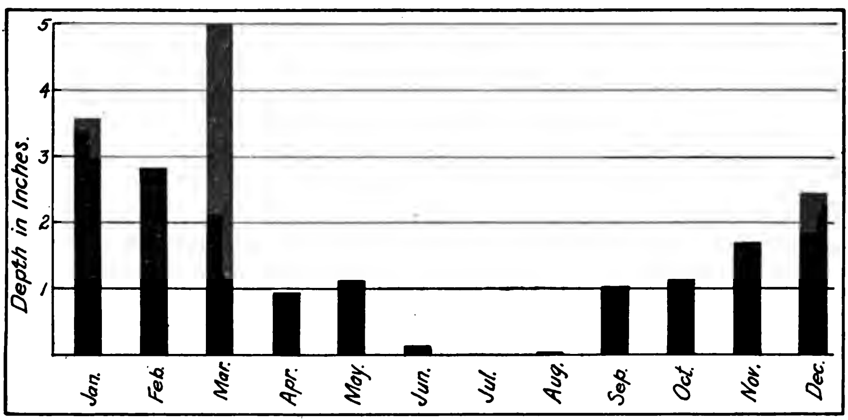

FIG. 24.—Mean monthly precipitation at Orland, Cal., for three years, 1903, 1904, and 1905.

with sediment, and here averages 12 feet wide on the bottom and is 18 inches to 2 feet deep, with levees at places 12 inches higher. Owing to the poor condition of its banks the canal will carry at its lower end but 40 cubic feet per second. The main laterals are about 4 feet wide and about 12 inches deep, and when free from weeds will carry a good head of water. Their combined capacity is about 30 cubic feet per second. The original construction gave the water in the canal a greater velocity than the material through which it flowed would stand; hence the erosion spoken of above. Not until several years later was the idea of drops conceived. Then the company created several crude drops by dumping a few loads of bowlders into the canal in several places. This was quite effective, but the water still carries a great deal of sediment, although when entering the canal it is quite clear. Originally there was a head gate at the point of diversion,

but the flood waters of the creek carried it away soon after it was built, and it has never been replaced. At present the water is diverted into the canal by throwing up with scoop scrapers a small gravel dam diagonally across the bed of the stream. This is unsatisfactory, as it must be rebuilt after each flood flow.

The entire canal system is simple and incomplete. As stated above, there are no headworks, and with one exception neither bridges nor culverts have been built. Where public highways cross the canal vehicles are compelled to ford the stream. There are five diversion weirs on the canal. One is a frame made of 2 by 4 inch timber and so constructed that long flashboards may be adjusted to raise the water high enough to flow into the lateral above. No arrangement is made to prevent erosion by the overflow. The other four diversion weirs are flumes 10 or 12 feet long and 8 or 10 feet wide, equipped with flashboards so that the water may be raised to the required height. The laterals leave the canal from cuts in the bank with no consideration of erosion. This poor construction causes an endless inconvenience, as the mud and sandbars deposited in the mouths of the laterals must be removed at each irrigation.

SEEPAGE LOSSES.

The following measurements were made on the canal of the Stony Creek Irrigation Company during the season of 1907 for the purpose of determining the loss by seepage and evaporation. Those of May and June were made by T. H. Humphreys, of the Reclamation Service, and those of July by J. E. Roadhouse, of this Office. Station 1 is at the head of the canal, while the other stations mentioned are located by their respective distances from the head.

Seepage losses from canal of Stony Creek Irrigation Company.

Date.	Station Nos.	Distance.	Discharge.	Total loss.		Loss per mile.
		Miles.	*Cu. ft. per sec.*	*Cu. ft. per sec.*	*Per cent.*	*Per cent.*
May 15	1 to 3	3.33	80.00	5.80	7.25	2.17
	3 to 4	2.20	68.40	1.60	2.34	1.06
May 31	1 to 3	3.33	60.10	5.40	9.00	2.70
	3 to 4	2.20	48.70	5.40	11.10	5.05
June 19	1 to 3	3.33	34.30	5.20	15.20	4.56
	1 to 5	7.80	34,30	7.50	21.90	2.81
	3 to 5	4.47	29.10	2.30	7.91	1.77
	1 to 6	8.20	34.30	10.20	29.80	3.63
	5 to 6	.40	19.30	2.70	14.00	3.50
July 25	1 to 2	3.20	24.18	4.59	18.98	5.92
	2 to 7	6.20	16.65	8.93	53.63	8.65

At station 3 the canal crosses Hambright Creek. Here measurements were made before the water entered the creek and again after it left it. The difference between the two is the amount wasted into Hambright Creek. This, of course, was not considered as seepage, but total loss.

The loss by evaporation is very small when compared with the total loss, so the total loss is due almost entirely to seepage. The loss, especially during the latter part of the season, could be reduced to some extent by better alignment and cleaner ditches. Under the present conditions it is doubtful whether the company would be justified in spending the amount of money necessary to line its canals with some expensive impervious material, such as cement plaster or concrete; but it has been shown in recent experiments with various canal linings by Mr. B. A. Etcheverry[a] that, next to the cement mortar, heavy oil lining is the most efficient, and it is very much cheaper. By the use of oil the seepage would be reduced perhaps 50 per cent and weed growth would be prevented, thus minimizing the resistance to flow and allowing a greater discharge within the limits of the present embankments.

IRRIGATED CROPS AT ORLAND.

The conditions in the vicinity of Orland are the same as in nearly all the grain-growing districts in the western half of the Sacramento Valley, which have been described in other parts of this report.

In 1897 the Orland Citrus Association planted 20 acres of trees, which were irrigated. This was the most extensive irrigation practiced in the vicinity of Orland since the building of the canal. Before this a few acres of prune trees about 8 miles up the canal near its head had been irrigated. It was not until the year 1900 that the citizens and farmers took an active interest in irrigation. The Stony Creek Irrigation Company reorganized at that time, extended its system, cleaned out the canal and distributing ditches, and put the system in working order. Land companies subdivided small tracts into 10-acre lots, and before two years had passed land was graded and alfalfa was being planted. At present there are nearly 300 acres of alfalfa and over 100 acres of trees and gardens irrigated under the Stony Creek Irrigation Company Canal. Citrus fruit ripens extremely early and oranges are of fine quality. There has been enough diversified farming, enough dairying, and enough fruit raising in and near Orland to show conclusively that, with the application of water, all agricultural and horticultural pursuits can be carried on profitably.

The farmers at present work under disadvantages, especially concerning the water system, upon which rests the success or failure of their crop. On account of the cessation of flow in Stony Creek the farmers do not depend upon water later than the 1st of July. They raise in this time about three crops of alfalfa, with pasture in the fall.

The season of 1906 was exceptionally late and wet, and most farmers

[a] California Station Bul. 188.

raised four crops of alfalfa, with good pasture in the fall. If water could have been obtained after the last cutting five splendid crops could have been harvested.

In 1906 surveys were made on Stony Creek by the United States Reclamation Service for the location of a storage reservoir for the retention of the flood waters of the creek. The water is to be used on the lands in the vicinity of Orland. In 1907 the plans for the dam and diversion weir were about completed. Under the present company the farmers pay for water $3.50 per acre for more than 1 acre, and $5 per acre for 1 acre or less, and take their chances of the water holding up during the season. The company issues no water rights, but the water is sold as so much merchandise, without written contract. There is no method of measurement used by the company and no definite amount of water is sold. During the early part of the season, when the water is plentiful, the farmer helps himself to all the water his ditch will carry, and uses it as long as he desires. For the most part the fields have not been well graded, and it takes an enormous amount of water to reach the high places. This necessitates a great waste of water. The waste water is often drained from one piece of alfalfa to the next piece below whether it be beneficial or injurious to the crop. When the water lowers later in the season and every available drop is valuable, the farmers under the first laterals along the canal receive the greatest benefit. The farmers at the lower end of the system during a shortage of supply believe that each should have an equal share of the water available. To this end each takes a very small portion of the flow for a few hours. The result is no one gets more than one check of his field irrigated. The water seeps away into the first check, disappears into the ground, and no water collects for the irrigation of the next check below. If one irrigator would take all the water for a limited time, and all take in turn, the results would be much better.

EXPERIMENTS.

The main object of the field experiments carried on in the vicinity of Orland was the determination of the amount of water used by the farmers under usual conditions. It was impossible under the existing conditions to measure the water used on every irrigated farm, but the few on which measurements were made were selected with care, representing average conditions.

The land irrigated at present under the canal of the Stony Creek Irrigation Company is gravelly, with here and there more or less clay loam, and is not altogether typical of the soil of the entire valley. On the north side of Stony Creek a few acres are irrigated under the

Lemon Home Canal, but the intake of that canal is below that of Stony Creek Irrigation Company Canal, and the water is cut off early in the season. And, again, the land was so poorly prepared that a very large amount of water is required each irrigation to reach the high places. The water is drained off finally through several openings on the lower side of the field where accurate measurements of the amount lost would have been impossible. While the land on the north side of Stony Creek is more representative, it was thought under the adverse circumstances the experiments should be carried on only on the south side of the creek.

The following methods were used in determining the amount of water used, weights of crop, etc. In each lateral there is more or less leakage, and to include this loss in the amount of water used would be erroneous. To eliminate these losses, measuring flumes were installed in the laterals where they entered the fields. These flumes were made of ⅞-inch shiplap lumber dressed on the inside. They offered very little resistance to the water and were water-tight. Each was made to accommodate the stream of water that flowed through the given lateral. The sides were perpendicular to the bottom. At right angles to the direction of the stream the flumes were quite level, but in the direction of the stream they were given a slight fall. Not having water registers at hand, we were compelled to resort to other means of measurement, which, however, proved nearly, if not quite, as efficient as the registers, but required more attention. A gauge reading to hundredths of a foot was placed inside each flume. This was read generally every hour throughout the day, or at least whenever the flow of water changed. Current-meter measurements were made at enough different heights to obtain a curve from which the discharge could be read for any given gauge height. There were no measuring devices for the waste water, but in each case the water was measured as it flowed in the waste ditch, and careful estimates were made, which are quite accurate. The total quantity entering a field is used in computing the "gross duty." This quantity less waste is used in computing "absolute duty." In determining the amount of hay produced, one to three loads of hay were weighed at each cutting. Multiplying the net weight of the average load by the number of loads hauled gives the amount of hay at the cutting.

EXPERIMENT I.

The results of this experiment are rather startling at first glance, and it would be to the credit of the land to eliminate them altogether; but, as this experiment shows very nicely several points other than the duty of water, we will consider it among others. The soil of this

field is made up almost entirely of gravel, having less clay or clay loam than any of the fields used for the other experiments which follow. The field contains exactly 16.6 acres, planted to alfalfa. The surface of the field is rather irregular and levees are built on contours.

Date of each irrigation and amount of water applied in Experiment No. 1.

Irrigation.	Date.	Days between irrigations.	Water used.	Average head.	Time water ran.	Depth of water applied.[a]
			Acre-feet.	*Cu. ft. per sec.*	*Hours.*	*Feet.*
First	May 19		52.85	4.4	145	3.18
Second	June 26	38	55.32	5.1	131	3.33
Third	July 15	19	10.27	4.3	29	.62
Fourth	July 26	42	11.15	5.6	24	.67
Fifth	August 3	8	[b] 13.73	4.9	34	.83
Sixth	August 17	14	15.63	4.2	45	.94
Seventh	September 11	25	15.95	2.7	72½	.96
Eighth	September 25	14	17.21	3.6	58	1.04
Ninth	October 19	24	14.94	4.1	44	.90
Tenth	November 12	24	43.40	7.0	79	2.61
Total			250.45			15.08
Mean		23.1		4.59	66.15	

[a] On this particular tract no water ran off and was wasted but all soaked into the gravelly soil.
[b] This water was run upon the land merely because it was convenient to do so.

There is a marked difference between the third and fourth irrigations compared with the first two. We find that in all the experiments except this one the first irrigation was larger than any one following. This may be due to the loose condition of the soil after the winter and the opening of the ground by the renewed activity of the roots during the spring. Under these circumstances we are not surprised at the abnormal amount of water used upon this tract the first time, but where the amount of the second irrigation exceeds the first we must look for the cause.

The average head of water used in the first two irrigations was 4.75 cubic feet per second. The average head of water used in the third and fourth irrigations was 4.95 cubic feet per second—a very small difference. The ditches may have been in a little better condition after the first two irrigations, yet the great difference in results was due to the methods used. The first two irrigations were performed by one who tried to irrigate too great an area of the field at one time. The water was divided into many small streams, which would not discharge water into the checks fast enough to raise it to a sufficient height to cover the high places in the somewhat poorly leveled field, and after a certain static head was reached the water would pass into the gravelly soil almost as fast as it would run into the check. It would take hours to fill a check sufficiently to use the drainage for the check below. The third and fourth irrigations were per-

formed by the owner of the land himself, and the results show that he used better methods. With practically the same head he irrigated the same area in about one-fifth the time. He ran the water all in one lateral and began by filling the lower check first. This was easily accomplished, because the water was forced over the surface before it had a chance to soak away. He proceeded in the same manner to the checks above until he reached the highest checks in the field. When he had finished, the water went to the man next below.

If the owner were paying for the water by the miner's inch or cubic foot per second, his land would have to be valuable indeed to use 3 feet of water over the surface eight or ten times each year, not considering the cost of labor. The use of this extravagant amount of water was due almost entirely to improper methods of irrigation.

The short time between the fourth and fifth irrigations is noticeable. One of these irrigations was unnecessary, but was given because the water was convenient. The alfalfa was cut the first day of August. Some farmers irrigate just before the crop is cut, while others irrigate immediately after the hay is off the field. There are advantages and disadvantages in each practice. There was, however, no reason for irrigating after the short interval of eight days when the last irrigation was a good one.

It is often harmful to use too much water upon alfalfa, even when there is no danger of scalding. The owner of this tract of alfalfa has noticed that the blossoms have been blasted and the plant stunted by an excessive use of water when the weather was cool.

Crops produced.—This alfalfa is 4 years old and the stand is even. The last crop had mixed with it considerable barnyard millet. The following table gives the yield and value of hay cut from 16.6 acres:

Yield and value of alfalfa, Experiment I.

Cutting.	Date.	Time between cuttings.	Total crop.	Yield per acre.	Value per ton.	Total value.
		Days.	*Tons.*	*Tons.*		
First	May 17		23.85	1.43	$6.00	$143.10
Second	June 25	39	26.60	1.60	6.00	159.60
Third	Aug. 1	36	29.31	1.77	6.00	175.86
Fourth	Sept. 6	36	20.00	1.20	6.00	120.00
Total			99.76	6.00		598.56

A fifth crop could have been cut and would have yielded a ton to the acre, but the owner thought it more profitable to use it as pasture for young cattle. He was offered $3.50 per acre for the pasture until the 1st of January, which would have paid the cost of the irrigation water for the season.

The following cost data will be found thoroughly reliable. The first cutting was cared for by contract and was underestimated. The cost of irrigation is a little high on account of the great number of irrigations and length of time for each.

Summary of costs and returns for irrigating, Experiment I.

One man, irrigating or harvesting, per day	$2.00
Man and team, hauling hay, per day	3.50
Man and team with mowing machine, including sharpening knives, per day	4.50
Cost of water for the season	58.10
Cost of first two irrigations	15.00
Cost of next seven irrigations	27.00
Cost of first cutting	22.50
Cost of second cutting	31.00
Cost of third cutting	31.00
Cost of fourth cutting	27.25
Cost of cleaning ditches	15.00
Interest on investment at 6 per cent, considering the land worth $100 per acre	99.60
Taxes, 15 mills on the dollar, 50 per cent valuation	12.45
Total	348.90
Value of hay, 99.76 tons, at $6 per ton	598.56
Amount refused for pasture, 16.6 acres, at $3.50 per acre	58.10
Total receipts	656.66
Total expense	338.90
Total profits	317.76
Profit on investment, 19.1 per cent.	

These results show conclusively that alfalfa growing, even upon a small acreage, is profitable.

EXPERIMENT II.

This field of alfalfa contains 20.1 acres. It had been planted some four years, and is owned, together with about 20 acres more, by a dairyman, who uses the hay and pasture for feeding dairy stock.

The surface of this field is decidedly irregular, and contour levees were run in each direction to insure a complete irrigation. Better preparation of the land before planting, with better alignment of laterals and fewer levees, would have proved more economical in the end. The fact that this soil is a little heavier than that of Experiment I accounts for the smaller amount of water used. A large portion of the upper end of the field was covered more or less with silt from storm waters carried by the canal in winter.

After each irrigation an extra amount of water was allowed to flow over the land, which drained through a draw across an adjoining

field and was used to irrigate a neighbor's alfalfa field. This was the only means by which the neighbor mentioned could irrigate his alfalfa. This frequently necessitated an estimate of time and amount of water.

Date of irrigation and amount of water applied to 20.1 acres in Experiment II.

Irrigation.	Date.	Time between irrigations.	Water measured.	Water wasted.	Water used.	Average head.
		Days.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Cu. ft. per sec.*
First	May 19 [a]		47.70	None.	47.70	4.8
Second	June 15	27	18.28	3.36	14.92	4.6
Third	July 7 [a]	22	17.90	None.	17.90	4.6
Fourth	July 27 [a]	20	11.44	None.	11.44	5.2
Fifth	Aug. 7	11	15.95	None.	15.95	3.9
Sixth	Aug. 24 [b]	17	18.24	None.	18.24	4.3
Seventh	Sept. 9 [c]	16	2.47	None.	2.47	2.6
Eighth	Sept. 30 [b]	21	20.78	None.	20.78	2.2
Ninth	Nov. 2	33	9.77	None.	9.77	3.4
Totals and averages		20.9	162.53	3.36	159.17	3.96

[a] The reason there appears to be no waste water is because the actual time of irrigating this one field only was taken, and water running through the field laterals afterwards to irrigate an adjoining field was not considered.
[b] The owner did not get a satisfactory irrigation this time, owing to a noncontinuous flow of water in the ditch.
[c] Partial irrigation. Water ran into a few checks only.

Crops.—This stand of alfalfa is not ideal. There are numerous bare spots in the lower end of the field, caused either by standing water or no water at all. During the latter part of the season barnyard millet predominated over the alfalfa and smothered it out to a certain extent. In two or three small spots dodder was discovered.

The most pernicious weed found in the vicinity of Orland is barnyard millet. Wherever there is moisture it grows very rank, and often reaches a height of 3 or 4 feet. During the early part of the season it fills the ditches and laterals and retards the flow of water to a great extent. Later this grass begins to grow in the fields and, owing to its rank and rapid growth, tends to smother the alfalfa. It is not without value for hay, but is nevertheless undesirable. The plant is an annual, growing, fruiting, and reseeding profusely, and then dying completely. The seeds, however, are in the laterals, where they germinate and grow the following year or are carried with the water to the fields. The remedy is obvious. The grass should be cut before the seed ripens. If necessary, this should be done a couple of times each year. Luckily, dodder has not gained a footing as yet, but if not checked will spread rapidly. It has no roots in the ground, and can easily be destroyed by cutting off all stalks of alfalfa upon which this plant is growing, and burning them.

The following table gives the yield on 20.1 acres and value of the crop for season of 1906:

Yield and value of alfalfa, Experiment II.

Cutting.	Date of cutting.	Time between cuttings.	Total crop.	Yield per acre.	Value per ton.[a]	Total value.[a]
		Days.	*Tons.*	*Tons.*		
First[b]	May 15		31.54	1.57	$10.00	$315.40
Second	July 6	52	27.50	1.37	10.00	270.50
Third	August 6	31	18.80	.93	10.00	188.00
Fourth	September 22	47	10.29	[c].51	10.00	102.9[illegible]
Total			88.13	4.38		876.80

[a] The value assumed is $10 per ton, realized in feeding to dairy stock.
[b] Pastured for a while in the spring.
[c] This includes 5 acres too poor to cut.

The fifth crop was pastured. It would have yielded about the same as the fourth crop had it been cut, but it was considered better to pasture than to cut it.

Itemized cost data for production of this hay was not available. We were able, however, to obtain the total cost per cutting. The cost of irrigation is taken at $2 per day for labor. This is more than the actual cost on account of the irrigator devoting most of his time to something else while he was running the water.

Summary of costs and returns for alfalfa, Experiment II.

Cost of water for the season, 20.1 acres	$70.35
Cost of nine irrigations	45.00
Cost of first cutting	48.84
Cost of second cutting	52.25
Cost of third cutting	40.00
Cost of fourth cutting	25.25
Cost of cleaning ditches	10.00
Interest on investment at 6 per cent, considering land worth $100 per acre	120.60
Taxes, 15 mills on the dollar, 50 per cent valuation	15.07
Total	427.36
Value of hay, 88.13 tons, at $10 per ton, fed to dairy stock	881.30
Value of pasture, 20.1 acres, at $3 per acre	60.30
Total receipts	941.60
Total expense	427.36
Total profits	514.24

Profit on investment through dairy, 25 per cent.

EXPERIMENT III.

This tract of land has a gravelly soil, with considerable clay loam present. The land was well prepared before planting, and the surface had a uniform slope. The checks are rectangular, with low levees. The exact area of the field is 12.2 acres. The amount of water used was not excessive, but could likely have been cut down 10 or 12 inches with more careful handling, cleaner ditches, larger head, and more dependable water supply. It would save much water to have the laterals so arranged that the lower checks might be irrigated first, working back to the higher checks.

The average head used during the season was only 2 cubic feet per second. It is impossible to irrigate gravel land with so small a head without using an unusually large amount of water, a part of which really does no good. The gravel land having such complete under drainage, the water merely soaks through the top layer of soil and percolates through the gravel beneath and passes off.

Date of each irrigation and amount of water applied in Experiment III.

Irrigation.	Date.	Time between irrigations.	Water measured.	Water wasted.	Water used.	Average head.	Time water ran.	Depth of water received by land. Gross.	Net.
		Days.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Cu. ft. per sec.*	*Hours.*	*Feet.*	*Feet.*
First	May 10	....	[a] 14.62	None.	14.62	2.8	62.5	1.19	1.19
Second	June 11	32	4.89	None.	4.89	1.6	36	.40	.40
Third	June 26	15	5.41	None.	5.41	2.4	27	.44	.44
Fourth	July 9	13	5.86	1.65	4.21	2.0	35	.48	.34
Fifth	July 21	12	[b] 8.99	1.00	7.99	1.5	75	.74	.65
Sixth	Aug. 4	14	7.74	.75	6.99	1.6	58	.63	.57
Seventh	Aug. 21	17	7.03	1.00	6.03	1.9	44	.58	.49
Eighth	Oct. 26	66	8.53	None.	8.53	2.4	43	.70	.70
Totals and averages		....	63.07	4.40	58.67	2.02	47.6	5.16	4.78

[a] The measuring flume was not adjusted when the first irrigation took place. At the second irrigation the irrigator used a head similar to the first, and, knowing the number of hours it took to irrigate the first time, the total amount of water used for the first irrigation was estimated.

[b] The water was shut off for 20 hours before the irrigation was quite finished. When water was turned on again it took a large amount to refill the upper checks in order to irrigate the lower ones.

This tract has been planted three years, and has one of the best stands of alfalfa in the vicinity of Orland. There are a few spots in the lower end of the field where the alfalfa has been burned out. The crop is as heavy on the levees as in any other portion of the field.

The following table shows an exceptionally good yield, especially from the first two cuttings. For some unknown cause the third crop was somewhat stunted and blossoms blasted, and the yield was not as great as it should have been. The fifth crop was left on the field as pasture. After the fourth cutting the alfalfa was dormant through

the whole month of September on account of scarcity of water. Had water been applied at the proper time the fifth crop would have been fully as large as the fourth, with as much pasture for the fall as there was under existing conditions.

The following table shows the yield on 12.2 acres and value of crop produced:

Yield and value of alfalfa, Experiment III.

Cutting.	Date of cutting.	Time between cuttings.	Total crop.	Yield per acre.	Value per ton.	Total value.
		Days.	*Tons.*	*Tons.*		
First	May 15		24.40	2.00	$6.00	$146.40
Second	June 25	41	22.40	1.84	6.00	134.40
Third	August 1	36	14.09	1.15	6.00	84.54
Fourth	September 6	36	13.20	1.08	7.00	92.40
Total			74.09	6.07		457.74

Cost data on Experiment III.

	First crop.	Second crop.	Third crop.	Fourth crop.
Irrigation		$10.00	$14.00	$10.00
Cutting and raking	$6.00	7.35	5.75	5.75
Shocking	4.00	4.50	4.00	3.00
Hauling [a] and stacking	18.00	10.25	7.00	7.00
Total	28.00	32.10	30.75	25.75

[a] The hay was hauled about a quarter of a mile.

Summary of costs and returns, Experiment III.

Cost of water for the season	$42.70
Cost of first crop	28.00
Cost of second crop	32.10
Cost of third crop	30.75
Cost of fourth crop	25.75
Cost of irrigation for pasture	4.00
Interest on investment, at 6 per cent on $100 per acre	73.20
Taxes, 15 mills on the dollar, 50 per cent valuation	9.15
Total expense	245.65
First three crops, at $6 per ton	365.34
Fourth crop, 13.2 tons, at $7 per ton	92.40
Value of pasture, at $2 per acre	24.40
Total receipts	482.14
Total expense	245.65
Net profits	236.49

Profit on investment, 19.4 per cent.

EXPERIMENT IV.

The area of the tract under consideration is 9½ acres. The fields used in the first three experiments are near each other and on the west side of the town. This piece of alfalfa is on the south side of Orland and about one mile from the others.

This soil is a heavy clay loam with a slight amount of gravel. The ground has a very uniform slope and was well prepared before seeding. The checks are each nearly one-third of an acre in area and are divided by low flat levees. On account of heavy soil and a splendidly prepared field less water was used on this tract than on any other. This probably comes nearer than any of the other experiments to showing the real water requirements of the greater part of the clay land in the vicinity of Orland.

Date of each irrigation and amount of water applied, Experiment IV.

Irrigation.	Date.	Time between irrigations.	Water measured.	Water wasted.	Water used.	Average head.	Time water ran.	Depth of water received by land.	
								Gross.	Net.
		Days.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Cu. ft. per sec.*	*Hours.*	*Feet.*	*Feet.*
First	May 19	....	4.70	None.	4.70	2.1	27	0.49	0.49
Second	June 12	24	4.04	1.66	2.38	2.4	20.5	.43	.25
Third	June 19	7	2.28	.66	1.62	2.3	12	.24	.17
Fourth	July 5	16	3.67	.50	3.17	2.6	17	.39	.33
Fifth	July 15	10	2.50	.42	2.08	1.1	28.5	.26	.22
Sixth	July 26	11	3.03	.40	2.63	1.5	24	.32	.28
Seventh	Aug. 11	16	2.65	.44	2.21	1.5	21	.28	.23
Eighth	Sept. 1	20	2.52	None.	2.52	1.1	28	.27	.27
Ninth	Sept. 26	25	1.61	....do....	1.61	.65	30	.17	.17
Tenth[a]	Oct. 16	20	2.19	....do....	2.19	....	....	.23	.23
Totals and averages		16.6	29.19	4.08	25.11	1.70	23.1	3.08	2.64

[a] This irrigation was performed by allowing the water to run upon the ground as it would. It usually ran a few hours at a time, and then only a small stream, which often ran in the night, so that it was impossible to measure it. An estimate was made based upon previous irrigations and the prevailing conditions.

This piece of clay soil absorbed less water at each irrigation than the gravelly soils, but it also dried out sooner and required more frequent irrigations of a few hours each.

Crops.—The following table gives the yield and value of the crop harvested on 9½ acres:

Yield and value of alfalfa in Experiment IV.

Cutting.	Date of cutting.	Time between cuttings.	Total crop.	Yield per acre.	Value per ton.	Total value.
		Days.	*Tons.*	*Tons.*		
First	May 17	....	19.00	2.00	$6.00	$114.00
Second	July 2	46	18.90	1.99	6.00	113.40
Third	August 5	34	11.81	1.24	6.00	70.86
Fourth	September 13	39	11.40	1.20	6.00	68.40
Total	....	....	61.11	6.43	....	366.66

This field of alfalfa is three years old and yields an exceptionally fine crop.

It is a little more difficult to secure a large yield of alfalfa upon a clay soil the first two years after it is planted than it is on a gravelly soil. When it reaches that age growing in a clay soil where it will absorb sufficient moisture the crop does as well at less expense than on a gravelly soil.

The lessee kept no accurate account of the cost of production of his hay, but a careful estimate was made. He paid land rental and water charges on 10 acres.

Summary of cost data.

Cost of water for the season	$35.00
Land rental, at $6 per acre	60.00
Irrigation	6.00
Cutting and raking	20.00
Shocking	12.83
Hauling and stacking	44.00
Total expense	177.83
Value of crop, 61.11 tons, at $6	366.66
Value of pasture, at $2 per acre	19.00
Total receipts	385.66
Total expense	177.83
Total profit	207.83

In these estimates no account is taken of value or wear on implements used. The low cost of irrigation is accounted for by the fact that the lessee did his own irrigating. He would set the gates and allow the water to run from one check to another until all checks were watered. He performed other duties while irrigating, and did not go to the field more than two or three times a day.

The farmers in general received $6 per ton for their hay in the stack in the field. The hay was purchased by local buyers and shipped to San Francisco markets.

EXPERIMENT V.

This experiment was carried out on 9½ acres of alfalfa adjoining the tract considered in Experiment IV. The soil is a clay loam with an occasional spot of gravel. The alfalfa is but two years old, and the experiment shows very nicely what one may expect from a newly seeded field upon clay land. One year earlier the conditions on the tract used in Experiment IV were the same, and practically the same results were obtained, which tends to confirm the results of the present experiment.

The alfalfa plant seems to grow more slowly in clay than in gravel, and the roots do not loosen up the soil the first two years sufficiently for the water to percolate to a very great depth. With lack of shade from the plant a rapid evaporation of water from the surface results, requiring light but frequent irrigations.

The owner worked his land into splendid shape before seeding—much to his present advantage. The land has a gentle slope and is, in fact, almost level. The checks are uniform and the levees are low, serviceable, and not at all inconvenient in harvesting the crop.

With a head of 3 or 4 cubic feet per second the owner could irrigate the field thoroughly in ten hours.

Date of each irrigation and amount of water applied, Experiment V.

Irrigation.	Date.	Time between irrigations.	Water measured.	Water wasted.	Water used.	Average head.	Time water ran.	Depth of water received by land.	
								Gross.	Net.
		Days.	*Acre-feet.*	*Acre-feet.*	*Acre-feet.*	*Cu. ft. per. sec.*	*Hours.*	*Feet.*	*Feet.*
First	May 15		[a] 4.70	None.	4.70	2.1	27	0.49	0.49
Second	June 18	34	3.48	0.50	2.98	2.4	17.5	.37	.31
Third	June 26	8	1.61	None.	1.61	1.1	17	.17	.17
Fourth	July 5	9	1.81	.25	1.56	2.2	10	.19	.16
Fifth	July 12	7	1.90	.30	1.60	2.2	10.5	.20	.17
Sixth	July 21	9	2.29	.70	1.59	1.9	14.5	.24	.17
Seventh	July 27	6	2.34	.56	1.78	1.6	18	.25	.19
Eighth	Aug. 2	6	2.55	1.00	1.55	2.1	15	.27	.16
Ninth	Aug. 10	8	2.13	.75	1.38	1.4	19	.22	.15
Tenth	Sept. 10	31	[b] 3.72	None.	3.72	1.0	45	.39	.39
Eleventh	Sept. 23	13	1.93	None.	1.93	1.7	14	.20	.20
Twelfth	Oct. 5	12	[b] 1.90	None.	1.90			.20	.20
Thirteenth	Nov. 10	35	7.13	1.62	5.51	1.5	56	.75	.58
Totals and averages		14.8	37.49	5.68	31.81	1.8	21.9	3.94	3.34

[a] This irrigation took place before the measuring flume was adjusted, and the amount used was estimated from the first irrigation on the adjoining tract, which was irrigated later. The soil and other conditions were practically the same.
[b] The water ran slowly and intermittently.

It will be noticed that during the summer months water was used on an average every seven or eight days. The reasons for this were stated in a preceding paragraph. The frequency of irrigations and unnecessarily large amount of water applied the last irrigation make the total high.

The following table shows the yield on 9½ acres and the value of crops produced:

Yields and value of alfalfa in Experiment V.

Cutting.	Date of cutting.	Time between cuttings.	Total crop.	Yield per acre.	Value per ton.	Total value.
		Days.	*Tons.*	*Tons.*		
First	May 12		13.30	1.40	$6.00	$79.80
Second	June 16	35	7.50	.79	6.00	45.00
Third	July 20	34	6.00	.63	6.00	36.00
Fourth	Aug. 18	29	6.00	.63	6.00	36.00
Fifth	Oct. 19	62	5.48	.58	6.00	32.88
Total			38.28	4.03		229.68

Summary of costs and returns, Experiment V.

Cost of water for the season	$35.00
Cost of irrigation for the season	8.50
Cost of cutting and raking	25.00
Cost of hauling and stacking	30.25
Interest on investment of $100 per acre, at 6 per cent	60.00
Taxes, 15 mills on the dollar, 50 per cent valuation	7.50
Total expense	166.25
Value of crop, 38.28 tons of hay, at $6 per ton	229.68
Value of pasture, at $1 per acre	9.50
Total receipts	239.18
Total expense	166.25
Total profits	72.93

Profit on investment, 7.29 per cent.

New alfalfa on a clay soil will not yield as large net returns as alfalfa of the same age on gravelly soil, but after a few years the clay soil will produce as good hay, generally with a smaller amount of water.

EXPERIMENT VI.

The present conditions at Orland do not offer much opportunity for obtaining experimental data in fruit growing, which is still in its infancy. J. H. Barber, expert in fruit growing, furnishes the following data for this report:

A small 1.86-acre orchard of lemons offered the best advantages for measuring the water, so a small measuring flume was installed at the head of the main lateral. The irrigations were all practically the same, having been performed by the same man using the same methods and the same head of water each time.

The following table shows the date of each irrigation and the amount of water applied:

Water used on lemon orchard at Orland.

Irrigation.	Date.	Time between irrigations.	Water used.	Time water ran.	Average head.	Depth of water received by land.
		Days.	*Acre-feet.*	*Hours.*	*Cu. ft. per sec.*	*Feet.*
First	June 20		0.54	11.5	0.69	0.29
Second	July 6	16	.46	8.0	.69	.25
Third	July 23	17	.46	8.0	.69	.25
Fourth	Aug. 11	19	.46	8.0	.69	.25
Fifth	Aug. 22	11	.40	7.0	.69	.22
Sixth	Sept. 4	13	.46	8.0	.69	.25
Seventh	Sept. 22	19	.46	8.0	.69	.25
Totals and averages		15.8	3.24	8.4	.69	1.76

This soil is lighter than most of that in the vicinity. It absorbs water readily with no waste.

The method of irrigation was practically the same as flooding in checks. A furrow was plowed on each side of each row of trees in both directions. The furrows were run full of water, then dammed so that the whole area between the trees was wet, but no water reached the trees. The ground was not cultivated until after the fifth irrigation and again after the last. The evaporation from an uncultivated soil in this climate is enormous and fewer irrigations would have been necessary had the ground been properly handled after each irrigation. However, the results show a rather high duty as compared with the usual waste of water in the vicinity.

No definite cost data could be obtained from this small tract. The owner estimated the crop for 1905 to be 400 packed boxes from 218 eight-year-old trees.

EXPERIMENT VII.

A measuring flume was installed at the head of the lateral carrying water for the entire area south of the county road and west of the railroad tracks. At the beginning of the season it was thought possible to measure with this flume the water as it flowed upon each of the individual plats. But later it was found that, owing to several irrigators dividing the water without measurement, no accurate account could be kept of the amount of water used by each irrigator. Under these circumstances it seemed best to measure the water as it passed through the flume and to assume that for the season each portion of the land received the same amount of water.

Very accurate measurements were made at the flume throughout the season, and an account was kept of all the water running over this area and note was made of water absolutely wasted. There are 75 acres of alfalfa in the tract. There are also a few trees which receive no particular attention, and the water used upon them would be hardly worth considering. It was found at the end of the season that there had been applied to the 75 acres 289.02 acre-feet of water, making a total depth of 3.85 feet over the entire surface. This is the absolute duty. The average head of water used during the season as measured at the flume was 2.64 cubic feet per second. This head was often divided into smaller streams to accommodate two or more irrigators. Water covering the surface to a depth of 3.85 feet is somewhat excessive when we consider the scarcity of water at the end of the season. Had there been more water in the canals the fields would have received even more. This tract of 75 acres of gravelly soil can not be irrigated with a small head of water if economy is to be practiced.

EXPERIMENT VIII.

It was intended when this flume was placed at the head of this main lateral to measure all the water used in Orland east of the railroad track, but soon after the measurements were begun it was discovered that when one irrigator finished using the water he turned it into a gravel pit near at hand, where it all ran to waste, while others ran the water down the county road where it was impossible to obtain any measurements or estimates of the amount wasted. We have, however, the measurements of the total amount of water that flowed through this main lateral during the season, beginning May 16 and ending November 16. We also have the average duty of water on the alfalfa and a few trees. Assuming the duty to be the same over the entire area, we note that more than half the water flowing through this flume was wasted. One thousand seven hundred and fifty-one acre-feet of water passed through the main lateral during the season, which is enough to cover the irrigated area of 234 acres of trees, gardens, and alfalfa 7.48 feet deep. The average absolute depth of water used on alfalfa was 4.5 feet, and the depth used on gardens and trees was 1.62 feet. On 114 acres of alfalfa there was used 513 acre-feet of water, and on 120 acres of fruit and gardens, 194.4 acre-feet, making a total of 707.4 acre-feet, the amount of water necessary to raise the crops as they are raised in Orland at present. This leaves a waste of 1,034.6 acre-feet, or sufficient to cover the land to a depth of 4.46 feet.

Within the village of Orland there is a small orchard of 2 acres of citrus trees. There are 90 lemon trees, 5 years old; 40 lemon trees, 9 years old; 36 orange trees, 9 years old; and 9 olive trees, 5 years old. The trees have never had proper care and the fruit has generally been wasted upon the ground. Irrigation water is applied in furrows which are opened up at the beginning of the season and are not leveled with a cultivator until the end of the season. Irrigation water is obtained from a well by means of a No. 2 centrifugal pump run by a 3-horsepower motor. During the season of 1905 the exact number of hours of running the motor was obtained, and having measured the discharge of the pump we were able to determine the amount of water used upon the tracts for the season. This was found to be 2.8 acre-feet, or a depth of 1.4 feet over the entire surface. Irrigation began June 7 and water was used about every ten days until November 8.

SUMMARY OF EXPERIMENTS.

The beneficial results of irrigation are quite marked and much in evidence in the vicinity of Orland. A. D. Christian rented two adjoining fields for the season of 1906. One was planted to alfalfa and was irrigated. The other was without water and was used for pasture. He paid a rental of $6 per acre for the alfalfa land and

$3.50 per acre for the water, and cleared $200 on 10 acres. For the unirrigated pasture land the owner received but 50 cents per acre for the season. The value of irrigation is also shown in a comparison of raising wheat and barley on dry land with raising alfalfa on irrigated land. The following data were obtained from a dry rancher who farms several hundred acres. These data relate to the season of 1906:

Cost of raising grain without irrigation.

	Per acre.
Plowing for summer fallow:	
First plowing	$1.50
Second plowing	1.00
Seeding land:	
Barley seed	1.00
Wheat seed	1.25
Sowing	.65
Harvesting, with combined harvester:	
Cutting and thrashing	1.50
Sacks	.10½
Hauling, per sack	.05

Taking the yield for the season as wheat 7 sacks per acre and barley 10 sacks per acre, we find the cost of raising the wheat to be $7 per acre and of barley $7.20 per acre. Taking the average prices for this year, the dry-ranch farmer would clear $3 or $4 per acre, while the farmer who raised alfalfa by irrigation realized nearly $20 per acre above all expenses.

P. D. Bane holds 66 acres of bearing almond trees on the banks of Stony Creek. The land is a rich loam and subirrigates well during the first part of the season, but gets rather dry later. It was clearly demonstrated by the late rains this season that water applied to growing almonds tends to increase the size of the meats and causes them to fill out better than when left to ripen without the application of water.

The following table sums up the results of the various experiments carried on in Orland during the season of 1906:

Summary of irrigation data in experiments at Orland.

No. of experiment.	Area irrigated.	Number of irrigations.	Average time between irrigations.	Average head used.	Average time water ran.	Depth over surface. Gross.	Depth over surface. Net.	Crop.
	Acres.		*Days.*	*Cu. ft. per sec.*	*Hours.*	*Feet.*	*Feet.*	
I	16.6	10	23.1	4.59	66.2	15.08	15.08	Alfalfa.
II	20.1	9	20.9	3.96	55.8	8.07	7.90	Do.
III	12.2	8	24.1	2.02	47.6	5.16	4.78	Do.
IV	9.5	10	16.7	1.70	23.1	3.08	2.64	Do.
V	9.5	13	14.8	1.80	21.9	3.94	3.34	Do.
VII	75.0	....	....	2.64	....	....	3.85	Do.
Mean[a]	....	10	19.1	2.42	37.1	5.06	4.50	
VI	1.86	7	15.7	.69	8.4	1.76	1.76	Lemons.

[a] Owing to the abnormal results obtained in Experiment I it was omitted from the mean.

Summary of crop data in experiments at Orland.

No. of experiment.	Area irrigated.	Crop.	Number of cuttings.	Average time between cuttings.	Total crop.	Yield per acre for season.	Avera[ge] cutti[ng] per ac[re].
	Acres.			*Days.*	*Tons.*	*Tons.*	*Tons.*
I	16.6	Alfalfa	4	37.0	99.76	6.00	1.
II	20.1	...do	4	43.3	88.13	4.38	1.
III	12.2	...do	4	37.7	74.09	6.07	1.
IV	9.5	...do	4	39.7	61.11	6.43	1.
V	9.5	...do	5	40.0	38.28	4.03	.
Totals and averages	67.9			39.5	361.37	5.38	

No. of experiment.	Total value.	Value per ton.	Largest crop per acre.	Smallest crop per acre.	Total cost.	Aver[age] cost [per] ton.
			Tons.	*Tons.*		
I	$598.58	$6.00	1.77	1.20	$226.85	[illegible]
II	528.78	6.00	1.57	.51	291.69	[illegible]
III	457.74	6.18	2.00	1.08	163.30	1.
IV	366.66	6.00	2.00	1.20	117.83	[illegible]
V	229.68	6.00	1.40	.58	98.75	2.
Totals and averages	2,181.44	6.04			898.42	1.

FINAL SUGGESTIONS.

The conclusion that an unnecessary amount of water was use[d] this season on these crops is unavoidable, and in summing up th[e] whole of our investigations it seems best to make a few suggestion[s] regarding the economical use of water, which would reduce the cos[t] and give both the irrigators and the water companies greater satisfaction.

In the first place, the water should be measured. Charges fo[r] water should then be based on the quantity used, not on the are[a] served. Until this is done the irrigators will never use water economically. There are many methods and different units. For alfalf[a] the cubic foot per second proves the best, although many still us[e] the miner's inch. The miner's inch does very well for small head[s] but is inaccurate and inconvenient for large heads. There shoul[d] be a ditch tender, who should have every division box and head gat[e] under lock and key. It should be his duty to give to each irrigator upon application, a good working stream of water for the prope[r] length of time. When the water is scarce, he should arrange wit[h] the farmers a system of rotation in use, and it should be considered [a] misdemeanor for an irrigator to take water without permission. Th[e] company should keep its main canal and main laterals free from weeds and aquatic plants, and the farmers, if they expect to handl[e] water readily, in turn should keep their distributing ditches in first-class condition.